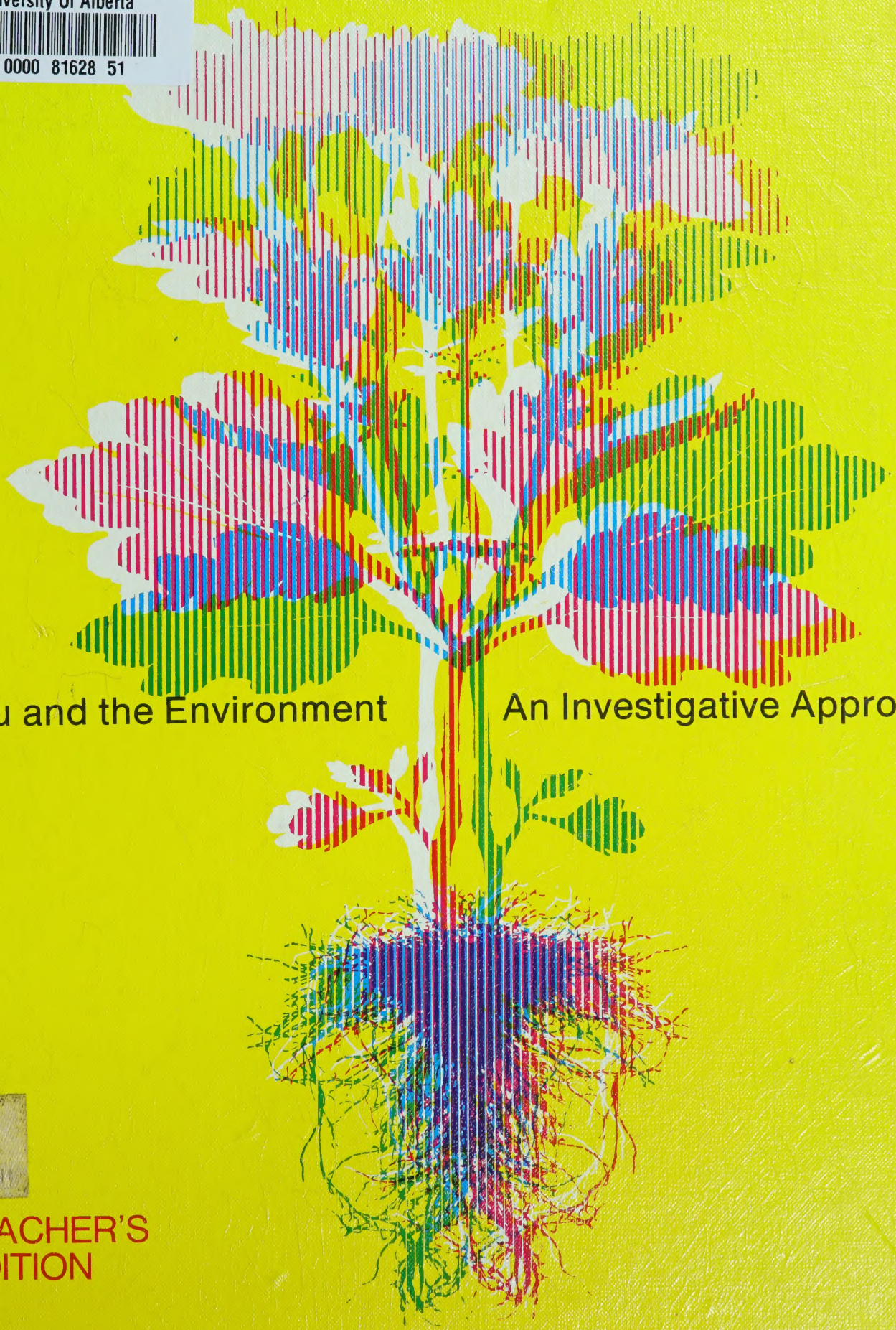
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You and the Environment

An Investigative Approach

TEACHER'S EDITION

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TEACHER'S MANUAL

You and the Environment

An Investigative Approach

Teacher's Edition: Manual and Annotations

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About the Program

You and the Environment: An Investigative Approach is a major revision of *Life Science Investigations: Man and the Environment,* a text that has been used successfully with many ability levels both as a life science program and as a course in environmental studies. *You and the Environment* continues and strengthens the emphasis on the role of living organisms in environmental problems.

A basic assumption behind the learning design of *You and the Environment* is that the essence of science includes "How do we find out?" as well as "What have we discovered?". Students must learn how scientific information is acquired as well as the information itself. Accordingly, *You and the Environment* has been structured so that students learn about living things as a direct result of their own investigative activities.

In this program, the students develop two complementary sets of skills. They learn to evaluate information that someone else has provided; and they learn to ask pertinent questions about their environment—questions that they can investigate and whose answers they can validate for themselves.

Organization of the Program

The program consists of four units that can be used equally well in the text sequence, in some other sequence of your choice, or independently, depending on the needs of the class. In Unit One, students develop inquiry skills through a series of Investigations into the structure, function, and behavior of organisms. (If your students have already mastered investigative skills in previous science classes, you may wish to begin with another unit or use only selected topics from Unit One.) In Unit Two, they use inquiry skills to focus on the way the environment influences the behavior of individuals and populations. In Unit Three, with the effect of the physical environment on living things as background, the students investigate a variety of interactions among organisms. In Unit Four, they investigate problems of air and water pollution, pesticide abuse, and other human intrusions on the environment. These problems are considered in terms of biological principles and social attitudes.

You and the Environment is a complete program consisting of a student text, an annotated Teacher's Edition, a laboratory supplement for recording data, progress tests (*Checkpoints*) in duplicating master form, and separately-published games. *The Mouse in the Maze* and *The Planet Management Game* are award-winning, computer-designed simulations. *The Planet Management Game, The Pollution Game,* and *The Redwood Controversy*® directly involve students in making and analyzing decisions about vital issues. Because the concepts in *The Planet Management Game* (Investigation 16-1) are not duplicated in other Investigations, it is recommended that this game, at least, be used with the text.

Goals of the Program

1. Students should demonstrate an inquiry approach to science and be able to design and carry out simple experiments with living organisms.
2. Students should understand the interaction between living organisms and the physical environment. They should recognize the complexities of ecological situations.
3. Students should be able to separate fact from opinion in a controversial ecological problem and state what social responsibilities are involved.
4. Students should be aware of individual variation in humans and other organisms and recognize the uniqueness of each living thing in both structure and behavior.

These goals, along with the objectives stated for each set of Investigations, provide standards for the program. The interests of both students and teachers will add depth and breadth to these objectives. *You and the Environment* should give students a better understanding of the world of living things and a greater ability and desire to investigate their environment.

19

Why is clean air important?

After you complete these Investigations, you will be able to

1. describe some methods for studying air pollution in a community.
2. identify the variables that affect how much air pollution people breathe.
3. use an experiment to show the effects of air pollution on plants.
4. infer, from data, some effects of air pollution on people.

On December 5, 1952, a thick fog rolled in over London, Eng-
st, because the city was
r, this fog did not burn
noke from homes and

← page 223

Analyzing data

Does your data support your hypothesis? Make a short report to the class. Do some people normally inhale more air than others do? What variables seem to change a person's breathing rate? If you moved to Tulsa would you breathe in less pollution? If you moved to Chicago would you breathe in more?

Perhaps the best evaluation of student achievement in this investigation is based on their reports. Determine if appropriate scientific methods were used and if the conclusions can be legitimately drawn from the data.

Investigation 19-4
How does sulfur dioxide affect plants?

Air pollution may make it difficult to grow plants in or near a city. Many trees cannot survive in city air. Even in areas far from cities, smoke and smog are damaging trees. Pine trees in a national forest 180 kilometres away from Los Angeles are being killed by smog. The smoke from power plants in Maryland kills as many as 300 000 evergreen trees each year. Smog also harms orange trees, lettuce, beets, and spinach.

What happens to the plants? Which parts are affected first? How long does the smoke take to do damage? Try a simple experiment to answer these questions. You will use a common kind of air pollution, sulfur dioxide. It is one of the gases that makes rainwater acid. Most of it comes from burning some kinds of coal and oil. Power plants and heating systems of homes and apartment buildings put a lot of sulfur dioxide into the air.

Materials

at least 2 plants
large plastic bag for each plant
small container
tape
2 g sodium sulfite (a chemical made of sodium, sulfur, and oxygen)
2 ml of 5% sulfuric acid (a chemical made of hydrogen, sulfur, and oxygen)

Sulfur dioxide has a very penetrating odor and is harmful if inhaled in moderate amounts. Care should be taken that the gas is generated only within the plastic bags. Make sure only you add the sulfuric acid to the sodium sulfite. Sulfur dioxide forms sulfurous acid when it reacts with water in the air. Therefore students should avoid prolonged contact with the condensate inside the bag. Dismantle the apparatus yourself. Wear goggles to protect your eyes. Rinse any plants you wish to save. Wash your hands thoroughly or wear rubber gloves.

Gathering data

Record the appearance of each of your plants before the experiment. You can draw or photograph them. Also, describe such things as the color of the leaves and any wilting you see.

If possible, have students take "before" and "after" photographs of the plants. Changes can often be observed within 24 hours. Generally, in a few days the plants lose their bright green color, wilt, and begin to turn brown.

page 231 ↑
page 232 →

Put one plant into the plastic bag. Set it down on the desk. Measure out 2 g of sodium sulfite. Put the sodium sulfite into a small container. Then put the container in the bag. Sulfur dioxide can be made by adding sulfuric acid to sodium sulfite.

Caution: These two chemicals should be mixed only in a closed container. Do not breathe the sulfur dioxide fumes. Ask your teacher to add the acid to the sodium sulfite.

After the acid is added, quickly seal the bag with tape or a wire tie. Use your other plant to control the experiment. Observe and record the appearance of each plant for two or three days.

Analyzing data

Compare your data with data from classmates who used the same kind of plant. Then exchange data with classmates who used a different type of plant. What conclusions can you draw? Does the kind of plant you used make any difference? Are plants with thick, waxy leaves affected the same way as plants with long, thin leaves? Are young plants more easily damaged than older plants?

ıp an uncontrolled exme to challenge it is sis of data.

Investigation 19-5
Can air pollution harm people?

› interested in learning an respiration can get biology and physiol-

Here is a diagram of the human respiratory system. To understand how pollution might affect respiration you must first know how the respiratory system works.

The large air passages into the lungs branch and divide. Eventually they end in millions of air sacs. These tiny sacs are smaller than the head of a pin. Here gas exchange takes place. Oxygen goes into the blood and carbon dioxide comes out.

The larger air passages are lined with cells that produce a sticky substance called **mucus** (MYOO kuhs). Other cells that line these passages have hairlike parts called **cilia** (SIHL ee uh). These cilia wave back and forth. They push the mucus up through the air passages to the throat where it is swallowed. The stream of mucus is like a conveyor belt. It carries particles out of the respiratory system. Almost 90 percent of the particles inhaled are caught in the mucus.

This cleaning system can be damaged. Sulfur dioxide and smoke can damage the cells lining the air passages. Then so

Features of the Program

You and the Environment makes extensive use of inquiry learning. Through experimentation, evaluation of results, and discussion, students develop the skills of asking and answering pertinent questions. The program is student-oriented. For the most part, students carry out their own Investigations. Objectives for the Investigations appear at the beginning of each section of student text. Self-check items, keyed to the objectives, are included at the end of each topic.

Investigation 19-4, which is designed to help the students complete the third objective on page 223, is typical of the Investigations in this program. This Investigation focuses on a real problem of current interest, where biology, technology, and society meet. The introductory paragraphs briefly present the problem and pose questions that help students plan their experiments.

As in all Investigations that require materials, the materials needed for one student group are listed in the student text. Notice the use of metric units. The metric system is used exclusively throughout the student text so that students develop an intuitive sense of metric measurement and skill in using the units without dependence on conversions.

section from page 231

Investigation 19-4
How does sulfur dioxide affect plants?

Air pollution may make it difficult to grow plants in or near a city. Many trees cannot survive in city air. Even in areas far from cities, smoke and smog are damaging trees. Pine trees in a national forest 180 kilometres away from Los Angeles are being killed by smog. The smoke from power plants in Maryland kills as many as 300 000 evergreen trees each year. Smog also harms orange trees, lettuce, beets, and spinach.

What happens to the plants? Which parts are affected first? How long does the smoke take to do damage? Try a simple experiment to answer these questions. You will use a common kind of air pollution, sulfur dioxide. It is one of the gases that makes rainwater acid. Most of it comes from burning some kinds of coal and oil. Power plants and heating systems of homes and apartment buildings put a lot of sulfur dioxide into the air.

Materials

at least 2 plants
large plastic bag for each plant
small container
tape
2 g sodium sulfite (a chemical made of sodium, sulfur, and oxygen)
2 ml of 5% sulfuric acid (a chemical made of hydrogen, sulfur, and oxygen)

Gathering data

Record the appearance of each of your plants before the experiment. You can draw or photograph them. Also, describe such things as the color of the leaves and any wilting you see.

Put one plant into the plastic bag. Set it down on the desk. Measure out 2 g of sodium sulfite. Put the sodium sulfite into a small container. Then put the container in the bag. Sulfur dioxide can be made by adding sulfuric acid to sodium sulfite.

Caution: These two chemicals should be mixed only in a closed container. Do not breathe the sulfur dioxide fumes. Ask your teacher to add the acid to the sodium sulfite.

After the acid is added, quickly seal the bag with tape or a wire tie. Use your other plant to control the experiment. Observe and record the appearance of each plant for two or three

section from pages 231 and 232

In the Teacher's Manual, the materials needed for a class of 28 are listed, along with estimated activity times, and recommended group sizes appropriate for the Investigations. We recommend that most Investigations be done in small groups so that more students can personally participate in each stage of an activity. The smaller the group, the more individual observations and perceptions can be emphasized.

In the *Gathering data* section, students are given instructions for carrying out the Investigation. In most Investigations, students are expected to make many decisions on their own. In this example, they must decide what controls are needed, what type of data to gather, and how to organize and record the data. However, directions for handling the chemicals are provided. The need for caution is emphasized with bold type and an underscore.

section from page T79

Investigation 19-4
How does sulfur dioxide affect plants?

Activity time: 1 class period to set up. During the next three days, the students observe changes in the plants while collecting data from the other Investigations.

Materials (groups of 2):
28 potted plants
10-ml plastic syringe or 10-ml pipette
100 g sodium sulfite
100 ml of 5 percent solution of sulfuric acid
28 clear plastic bags to cover plants
transparent tape, masking tape, or wire ties
2 balances

Preparation

Students can grow their own plants from seed. The seeds of rapid-growing plants such as green beans or peas should be planted two to three weeks before the Investigation. Seeds could be planted on different days, so that plants of different ages are available. Also, plants from previous experiments can be used, though their ages may be unknown. Several different types of plants should be investigated, for example, cabbage (waxy leaves), onion (thin leaves), tomato (hairy leaves).

For each experimental plant, 2 g of sodium sulfite and 2 ml of 5 percent sulfuric acid is recommended. Prepare the sulfuric acid solution yourself. Make up a 5 percent solution of sulfuric acid by pouring 10 ml

Materials

at least 2 plants
large plastic bag for each plant
small container
tape
2 g sodium sulfite (a chemical made of sodium, sulfur, and oxygen)
2 ml of 5% sulfuric acid (a chemical made of hydrogen, sulfur, and oxygen)

Sulfur dioxide has a very penetrating odor and is harmful if inhaled in moderate amounts. Care should be taken that the gas is generated only within the plastic bags. Make sure only you add the sulfuric acid to the sodium sulfite. Sulfur dioxide forms sulfurous acid when it reacts with water in the air. Therefore students should avoid prolonged contact with the condensate inside the bag. Dismantle the apparatus yourself. Wear goggles to protect your eyes. Rinse any plants you wish to save. Wash your hands thoroughly or wear rubber gloves.

Gathering data

Record the appearance of each of your plants before the experiment. You can draw or photograph them. Also, describe such things as the color of the leaves and any wilting you see.

If possible, have students take "before" and "after" photographs of the plants. Changes can often be observed within 24 hours. Generally, in a few days the plants lose their bright green color, wilt, and begin to turn brown.

section from page 231

In the Teacher's Edition, there are marginal annotations to the student text. These brief hints and cautions are located near the related sections of student text to help you, the teacher, with daily activities in the classroom. The annotations on page 231 are representative. One suggests safety procedures for handling both sulfuric acid and sulfur dioxide. The other is a brief discussion of possible results. A more detailed discussion of results can be found in the *Analyzing data* section notes on page T79 of the Teacher's Manual.

The *Analyzing data* sections include questions aimed at helping students reach conclusions about the Investigation. A range of conclusions is expected and encouraged, as long as the conclusions can be supported by data. Often the analysis of data produces new questions for students to investigate. Flexible, open-ended Investigations make it possible for students to explore what interests them. Since it is not essential to do all of the Investigations, the program is highly flexible.

section from page 232

serve and record the appearance of each plant for two or three days.

Analyzing data

Compare your data with data from classmates who used the same kind of plant. Then exchange data with classmates who used a different type of plant. What conclusions can you draw? Does the kind of plant you used make any difference? Are plants with thick, waxy leaves affected the same way as plants with long, thin leaves? Are young plants more easily damaged than older plants?

describe the variables in each situation that you used to order the photographs.

Extend Your View 19-3
Do automobile exhausts harm corn?

Can you use an experiment to show the effects of air pollution on plants? Some farmers whose land borders highways are worried about their corn. They have read that smog kills trees and crops around Los Angeles. Some of them think that exhaust fumes from cars and trucks are damaging their corn. But they do not have enough evidence.

Design an experiment that could be used to test their hypothesis. Write down the procedures you would follow. What evidence of plant damage would you especially look for? How would you control the experiment?

section from page 236

section from pages 328 and 329

You could also reason that either (E) and (F) or (B) and (F) could be switched. To make a more accurate determination, it would be necessary to know more about each environment.

Key 19-3
To test the hypothesis in a laboratory, you would need

1. to identify the types and amounts of automobile-exhaust gases along the highway.
2. to expose corn plants to these same types and amount of gases.
3. other corn plants growing under the same conditions, except without exhaust gases.
4. a way to measure results, such as observations of height, rate of growth, leaf color, number or size of ears of corn produced, or the quality and size of the corn kernels.

You might have decided to observe corn plants in the field. Your design should still include Items 3 and 4. Discuss your idea with your teacher.

Key 19-4
The graphs show that more smokers than nonsmokers die from lung cancer. Also, as smoking becomes heavier, the death rate increases. The larger the city, the greater the chance that a nonsmoker will get lung cancer. But whether or not people smoke is a more important variable than where they live.

Key 20-1
The data indicates that Lake Erie is more polluted than Lake Ontario. The table shows that Lake Erie has

1. a higher chemical oxygen demand.
2. more coliform bacteria.
3. more phosphorus.
4. more algae.

Key 20-2
The best answers to the questions probably are:

1—N 5—N 9—M 13—M 17—M

Extend Your View items at the end of each set of Investigations permit the students to check their grasp of concepts and skills. These items are keyed to the objectives at the beginning of each set of Investigations. Notice that Extend Your View 19-3 and Investigation 19-4 are keyed to the same objective—the third objective on page 223. Extend Your View 19-3 is not intended as a quiz or test. Its function is to permit the students to evaluate their own progress. Suggested answers are given in Appendix A.

The illustrations in *You and the Environment* are not simply adjuncts to the text. They add interest and motivation, extend the content, serve as data sources, and even provide additional informal investigations. Diagrams such as this example from page 232 frequently accompany *Gathering data* sections and are both functional and attractive.

The photographs from pages 188–189 comprise an independent activity in themselves, supplementing the formal Investigation, which deals with antibiosis. The excellent quality of these carefully selected illustrations provides a high degree of motivation and student-interest.

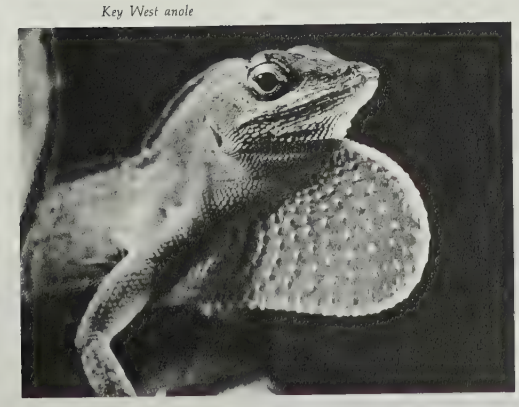


How does the appearance or the behavior of these animals help to protect them from predators?



opossum

Key West anole





true katydid

walking stick

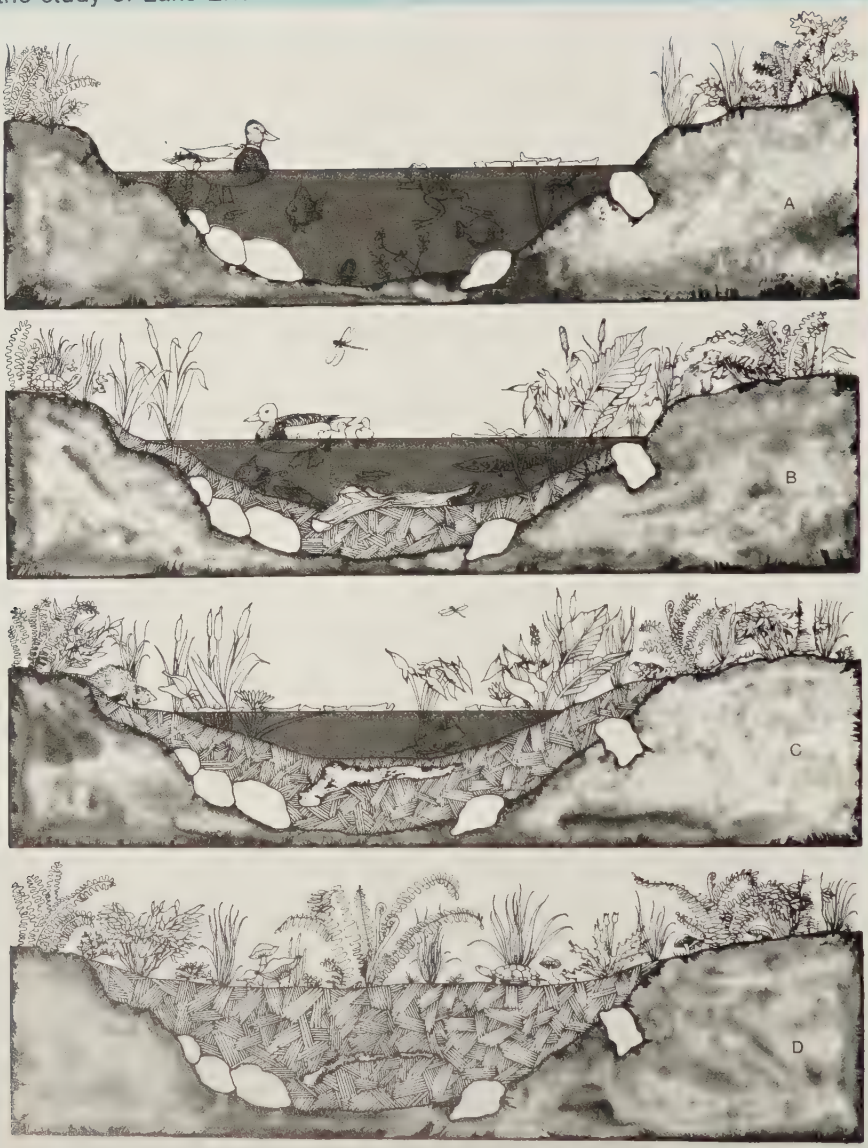


Many of the Investigations in *You and the Environment* will be familiar to users of *Man and the Environment.* Roughly 70 percent of these thoroughly classroom-tested and successful activities have been retained in *You and the Environment.* They have been revised and strengthened, where necessary, on the basis of feedback from the field. Information has been updated to make them current.

For example, Investigation 20-1 *What is happening to Lake Erie* replaces Problem 20-1 *What's wrong with Lake Erie?* The scope of the Investigation has been broadened to include both the United States and Canadian aspects of the problem and the whole approach to the study of Lake Erie has been revised. The aging of a lake is seen as a natural process; human intrusion simply acts as a catalyst—changing the rate of the process.

Investigation 20-2 is new as are roughly 30 percent of the Investigations in *You and the Environment.* The illustration on page 258 is an integral part of this Investigation. Students use the illustration to identify some of the changes involved in the process of eutrophication. Such changes are more effectively presented in visual form.

In addition, the course has been updated to include other areas of current concern such as acid rain, food additives, and energy needs.



Using the drawings, describe how this lake changed through the years.

Introduction

Rationale

A basic assumption behind the design of *You and the Environment* is that the essence of science includes the "how" as well as the "what." Students must learn how scientific information is acquired as well as the information itself. Accordingly, *You and the Environment* has been structured so that students learn about living things as a direct result of their own activities. Within certain boundaries, students can ask their own questions about their environment.

Another basic assumption of the program is that the fundamental ideas in environmental science have personal and social relevance. *You and the Environment* helps students develop concepts and insights about themselves and their environment. The fundamental ideas are presented in a context that is familiar to students. The ideas are used frequently and, as a result, they are retained. Transfer of the ideas to later courses and to adult life is easier because the learning situations are closely related to real-life experiences.

Even though there is a wide range of abilities and skills in any class, all students can be successful in this program. The goals of the program are well within their grasp. The emphasis on activities and psychomotor skills gives students who are not good readers a better chance of success.

Goals of the program

1. Students should demonstrate an inquiry approach to science and be able to design and carry out simple experiments with living organisms.
2. Students should understand the interaction between living organisms and the physical environment. They should recognize the complexities of ecological situations.
3. Students should be able to separate fact from opinion in a controversial ecological problem and state what social responsibilities are involved.
4. Students should be aware of individual variation in humans and other organisms and recognize the uniqueness of each living thing in both structure and behavior.

These goals, along with the objectives stated for each set of Investigations, provide standards for the program. The interests of both students and teachers will add depth and breadth to these objectives. *You and the Environment* should give students a better understanding of the world of living things and a greater ability and desire to investigate their environment.

There are behavioral objectives for each set of Investigations. The emphasis of these objectives is on gathering and using information, not on memorizing facts. In this technological age, the authors feel it is more important for students to have firsthand experience in learning to recognize problems and learning how knowledge is discovered and applied than it is for them to store information.

To make *You and the Environment* as concrete as possible and minimize abstractions, the focus of the entire program is on "skin-out" science. Students study organisms, populations, and ecosystems, not cellular or subcellular biology.

Features of the student text

The learner is presented with a series of problems, questions, or issues to resolve. Simulations are used as an integral part of the program to give students experience with complex situations.

Unit One has been carefully structured. These early Investigations require the greatest amount of teacher supervision. Many students have little experience in self-directed school activities. As students develop their skills and investigative abilities, they gradually assume more and more responsibility for their own learning. In the last unit, the students assume almost full responsibility for their activities.

Each set of Investigations has several recognizable components. A statement of the *objectives* to be achieved by the students precedes an *introduction* that poses questions and sets the stage for the *Investigations*. Finally, the *Extend Your View* section helps students check whether or not they have achieved the objectives.

The Investigations are grouped into four units, each having its own theme.

Unit One. Investigating living things
Students develop inquiry skills through a series of Investigations into the structure, function, and behavior of organisms.

Unit Two The environment affects living things
Using inquiry skills, students focus on the way the environment influences the behavior of individual organisms and populations. They investigate the needs of living things and the behavioral patterns that enable organisms to meet these needs.

Unit Three Living things affect each other
Having seen how the physical environment affects living things, the students now investigate a variety of interactions among organisms. The interactions with the physical and the biological environment are summarized in the concluding activity of this unit—*The Planet Management Game.*

Unit Four People affect the environment
Students shift their attention from an imaginary planet, Planet Clarion, to their own planet. They investigate the problems of air and water pollution, pesticide abuse, and other areas of human concern that affect the environment. These problems are considered in terms of both scientific principles and social attitudes.

The metric system is used exclusively throughout the student text to help the students gain a working knowledge of metric units without becoming dependent on conversions. In the Teacher's Manual, nonmetric units are sometimes used to indicate quantities of materials that are not available in metric units.

Features of the Teacher's Edition

This Teacher's Edition has been designed to give you as much assistance as possible in teaching *You and the Environment.* Annotations appear in the margins throughout the book. These brief hints and cautions are placed near the related sections of student text to help with daily activities in the classroom.

In the Manual, the pages in the front of the Teacher's Edition, there are these additional features:

1. A table of *behavioral objectives* and performances for each set of Investigations. The performances are keyed to the *Extend Your View* sections.
2. An *overview* that briefly describes the content of each set of Investigations.
3. *Background* sections to assist the teacher in techniques and subject matter.
4. *Section notes* for each Investigation. These will vary in content depending on the Investigation but will generally include a materials list for a class of 28, the activity time, directions for preparing materials, discussion of results, possible answers to the Analyzing data sections, and suggestions for optional activities.

The Manual does not contain long bibliographies of books and articles that most teachers cannot acquire or wade through. Instead, following the section notes for each set of Investigations are selected *References* and *Films.* The following basic references are readily available and constitute a useful reference library throughout the course.

Baker, Jeffrey J. and Allen, Garland E. *The Study of Biology,* 2nd edition, Palo Alto: Addison-Wesley Publishing Co., Inc., 1971.

Fraenkel, Gottfried S. and Gunn, Donald L. *The Orientation of Animals.* New York: Dover Publications, Inc., 1961.

Kalb, Haven et al. *High School Biology.* BSCS Green Version, 3rd edition. Chicago: Rand McNally & Company, 1973.

Morholt, Evelyn, Brandwein, Paul F., and Joseph, Alexander. *A Source Book for the Biological Sciences,* 2nd edition. Chicago: Harcourt Brace Jovanovich, Inc., 1966.

Smith, Robert L. *Ecology and Field Biology.* New York: Harper & Row, Publishers, 1966.

Welch, Claude et al. *Biological Science: Molecules to Man.* BSCS Blue Version, 3rd edition. Boston: Houghton Mifflin Company, 1973.

Teaching *You and the Environment*

The classroom

It is important in a study of the environment that students have frequent opportunities to observe and work with living things. Numerous aquariums and terrariums or other containers of living things—especially if set up and maintained by the students—will help immensely to generate enthusiasm for the course.

Several excellent guides for selecting organisms and setting up and maintaining aquariums and terrariums are available free to teachers from equipment supply houses. Two series of such guides are listed here.

Turtox Service Leaflets
CCM: General Biological Supply House, Inc.
8200 South Hoyne Avenue
Chicago, Illinois 60620

Ward's Curriculum Aid Series
Ward's Natural Science Establishment, Inc.
P.O. Box 1712
Rochester, New York 14603
or
P.O. Box 1749
Monterey, California 93940

Students should also have access to simple quantitative tools such as balances, metresticks, and graduated glassware. This will encourage the development of accurate and systematic patterns of measurement.

One is tempted to use last year's projects (with their personal associations) on bulletin boards and in display cases, or else to post timely illustrations. However, each year's students should be responsible for deciding how to use the bulletin boards and other classroom display areas. This responsibility will generate more interest than teacher displays and will help to change the students' perception of the classroom as the teacher's room to the students' room. That should create more positive attitudes toward science and school in general.

Finally, if you have a scientific question you yourself are investigating, students will note your interest and enthusiasm. This will help to establish a good classroom atmosphere.

Teacher-student interaction

It is essential that teacher behavior be consistent with the behavioral goals for the students. If the students find out, for example, that they really do not have to investigate the response of euglenas to light because you will explain it anyway, then the students probably will not investigate. Or if they do, they will not feel as involved in finding the answer. The joy of discovery will go out of the activity. To gain self-confidence, the students must be able to practice scientific strategies themselves and discover that they can be successful.

Your task is to encourage students to apply their intellect and experience to the problem at hand. By asking appropriate questions and supplying data not available to them, you will encourage the students to come to grips with an idea.

Students will also need your assistance to synthesize their experiences from each set of Investigations into a meaningful whole. You may have to provide missing data, ask questions that challenge the students to examine their evidence, and help groups share their findings. You are responsible for guiding the development of major concepts by the class. At first you will be largely caught up in helping students develop investigative skills. As the course progresses, you become the senior scientist or advisor assisting your junior colleagues in investigating the world of living things.

Evaluating student success

When students believe that they can direct at least a part of their learning—as they can in *You and the Environment*—you should begin to see positive changes in behavior. First, their interest and enthusiasm should be consistently higher. Second, they should ask significant questions much more frequently. These are obviously signs of success, and just as important as written evaluative devices.

The Extend Your View sections included with each set of Investigations enable the students to check their learning of the objectives for the Investigations. Most of the Extend Your View items ask the student to demonstrate investigative skills, as well as apply scientific knowledge. You should distinguish between the two kinds of goals when evaluating a student's performance. A student that knows the information but lacks the skills requires a different prescription than a student who has developed investigative skills but lacks the information.

Performance on Extend Your View items should not be used for assigning grades. Students finding out that their performances on these items are being graded may not accurately report their results, and will not receive the appropriate remedial work.

Checkpoints (duplicating masters available from Houghton Mifflin Company) are evaluation items written for each set of Investigations. A Checkpoint usually describes a situation that is related to the Investigation but, hopefully, is unique and challenging for the students. These items should be presented after students have worked on the Investigations and done the Extend Your View questions. If you prepare your own additional evaluation items, be sure the students know the objectives your items are testing.

Teaching schedules

There is great freedom to improvise when scheduling *You and the Environment.* Once students have mastered the inquiry skills in Unit One, a skilled teacher can arrange the rest of the Investigations to fit student needs, local resources, and administrative requirements.

The organization and format of *You and the Environment* lends itself to several different learning situations. The entire program may be used as a year course in environmental science. The four units may be used separately as mini-courses. Unit Four can be effectively used in a social science program.

Units Two through Four are carefully structured, but judicious reorganization of the Investigations is possible. In fact, once you are familiar with the program, you can look for ways to use the Investigations to create your own course in environmental science.

This general time table may help you plan your time. It is based on these assumptions:

1. The school year has approximately 180 days.
2. There are 5 science classes a week and each class is 40 minutes long.
3. The classroom is used exclusively for environmental science.
4. The students do not have learning disabilities.

In considering each set of Investigations, time has been included for summary discussions, evaluative items such as Extend Your Views and Checkpoints, and some additional activities.

General Time Table

	Set of Investigations	*Time*
Unit One	1	4 days
9–10 weeks	2	7 days
	3	7–8 days
	4	6 days
	5	7 days
	6	4–5 days
	7	4 days
	8	4–5 days
Unit Two	9	6–7 days
5–6 weeks	10	5–7 days
	11	9 days
	12	6–8 days
Unit Three	13	5–6 days
5–6 weeks	14	6 days
	15	7 days
	16	7–8 days
Unit Four	17	9 days
10–14 weeks	18	6–8 days
	19	9 days
	20	6–17 days
	21	5–8 days
	22	5–6 days
	23	5–8 days
	24	5 days

In learning about the nature of science, it is far more important that students enjoy what they do and do it well, than it is to rush through all the activities in the course for the sake of completing it. These alternative plans allow you to vary the emphasis you place on each unit of the program.

Plan A
1. Do all of Unit One carefully so students can develop the investigative skills needed for the rest of the year.
2. Pick from Units Two and Three the activities most interesting to your students but leave adequate time for Unit Four.
3. Do Unit Four.

Plan B
1. Do Unit One.
2. Do Unit Four.
3. Pick the most interesting activities from Units Two and Three for the remainder of the year.

Plan C
If your students have already mastered investigative skills in previous science classes:
1. Begin by doing Unit Four.
2. Use the remainder of the year for selected topics from Units One, Two, and Three, and student research problems arising from Unit Four.

Materials

The following table shows the materials needed for one class of 28 students. The amount of each material used and the Investigations in which it is used are indicated. This overall list will allow you to order all the supplies for the entire program at the same time. You will also have time to make arrangements to borrow those materials you do not wish to purchase.

The materials are organized according to location of purchase and whether or not they can be reused. Depending on your community, some of the items listed as available from supply houses may be available locally; for example, packets of seeds. You will notice that the living organisms are not divided into consumable and reusable categories. Whether the organisms can be reused will often depend on the care taken with them.

Materials that are considered optional are designated (O). However, what is optional in one Investigation (graph paper in Investigations 5-1 and 20-1) may be required in other Investigations (Investigations 6-2, 8-1, and 8-2). In these cases the (O) appears next to the listing for the Investigation in which the item is optional. Materials that involve advance preparation are indicated (AP). Details for these preparations are found in the section notes in the Teacher's Manual.

If you have more than one class taking this course, you will sometimes need a larger quantity of some reusable materials. An asterisk (*) indicates materials that will be tied up in a setup at least overnight. These materials will not be available for other classes that meet the same day. Either you will have to stagger the use of the materials by different classes or multiply the quantity in the list by the number of classes that you teach. Less often, materials may be tied up for extended periods and will not be available for later Investigations. Remember that chemicals must be purchased in standard quantities. You will sometimes have to order larger quantities than those specified in the list.

It is advisable to check the section notes in the Teacher's Manual for more specific information on some materials. For example, the goldfish used in Investigation 7-1 should be at least 7.5 cm long. Sometimes alternative materials are recommended in the section notes. In Investigation 9-2, drinking glasses or medicine bottles can be substituted for plastic Petri dishes.

Assumed, but not specified in the list, are some basic classroom supplies and equipment. It is assumed that you have a clock or watches with second hands, access to a refrigerator, paper towels, rubber bands, pens (marking pens, ball-point pens, felt-tip pens, glass marking pencils), and reference books. (The books will be especially useful in the more open-ended Investigations.)

Also not specified in this list are items to be used in Investigation 4-2 (collections of nonliving things) and Investigation 4-3 (collections of living things). The materials lists for these Investigations give extensive suggestions of items that are suitable. Many of these are available in the community for purchase (flower bulbs) or collection (animal or human hair). Some must be purchased from supply houses, but it is possible to use items that will be needed for later Investigations, such as pond snails needed for Investigation 6-1.

The type of burner used in this program is not specified. If you work with alcohol burners, be aware that alcohol fires can cause serious burns. Ask the fire department in your community for the laws on storage and use of flammable liquids. If you want to use gas burners but do not have outlets for Bunsen burners in your classroom, you can substitute small portable gas burners.

Materials List

Available from Houghton Mifflin Company *(Contact your local sales representative or regional sales office.)*

Editorial and International Sales:	One Beacon Street Boston, Mass. 02107	617/725-5000
Sales:	Pennington-Hopewell Road Hopewell, N.J. 08525	609/466-1950
	666 Miami Circle, N.E. Atlanta, Georgia 30324	404/262-1500
	1900 S. Batavia Ave. Geneva, Illinois 60134	312/232-2550
	6626 Oakbrook Blvd. Dallas, Texas 75235	214/631-5620
	777 California Ave. Palo Alto, Calif. 94304	415/324-4777

Material	*Amount*	*Investigation*
The Mouse in the Maze	5	8-2
The Planet Management Game	5	16-1
The Pollution Game	5	24-1
The Redwood Controversy®	1	22-1

Available from supply houses *Living Things*

Material	*Amount*	*Investigations*
culture medium, for Euglena	1 litre	10-1* (AP)
Elodea (*Anarcharis sp.*)	7 sprigs	6-1
mealworms (O)	7–14	6-2, 9-1, 9-2
microorganisms		
Euglena	1 culture	10-1* (AP), 10-2
Sarcina subflava	1 culture	15-1
Bacillus subtilis	1 culture	15-1
Bacillus brevis	1 culture	15-1
Streptomycus venezuelae	1 culture	15-1
seeds		
Choose from black locust, honey locust, or silk tree.	180	11-1*
corn	1 packet	6-2, 11-2, 11-3 (O)
cucumber	3 packets	11-2, 11-3 (O), 15-1
garden pea	3 packets	6-2, 11-2, 11-3
green bean	3 packets	6-2, 11-2
Merion bluegrass	0.3 lb.	15-1*
radish	4 packets	6-2, 11-2 (O), 11-3 (O), 15-1
Scorpion weed (*Phacelia*) and at least one other light-sensitive seed	120	11-3
other varieties	350 total	11-2, 11-3, 15-1
snails, pond	14	6-1*
sowbugs (O)	7–14	6-2, 9-1, 9-2

Available from supply houses *Laboratory Materials: Reusable*

Material	*Amount*	*Investigations*
balances		
double-beam 500-g capacity	2 or more	12-1, 19-4
pan	2	2-3
beakers		
250 ml	7	12-2, 12-3
600 ml Pyrex	7	11-1, 14-1
burners	7	6-1, 14-1, 15-1
calipers (O)	1–2	5-1, 5-2
clamps		
spring-type	7	14-1
support	7	12-2
diffraction grating (O)	1	10-2
files, triangular	3	9-2, 11-1
flasks, 125-ml Erlenmeyer	4	15-1
graduated cylinders, 100 ml	4	19-3
incubators (or constant temperature boxes)	1 or 2	11-2, 15-1
inoculating loop	1	15-1

Material	*Amount*	*Investigations*
magnifying glasses	8	2-3, 2-4
measuring tape, metric (O)	1	2-4
medicine droppers	14	10-1, 14-1, 15-1*
metresticks	14	2-3, 2-4, 5-1, 5-2
microscopes	7–14	10-1, 14-1, 19-2
overhead projector	1	3-3, 10-2
Petri dishes, plastic	60	11-1*, 11-2*, 11-3*, 15-1*
pipette, 10 ml	1	19-4
pH comparator color charts	4	19-1
prism (O)	1	10-2
ring stands and rings	7	12-2, 12-3, 14-1
rulers, metric	28	1-1, 3-2, 11-1, 12-2
slides, microscope	60	10-1, 14-1, 19-2*
stoppers, rubber		
#1, solid	21	6-1*
#1, one-hole	8	6-2
#0, solid	14	19-1
test tubes		
10 x 75 mm	36	15-1, 19-1
16 x 150 mm	24	6-1*, 6-2, 9-2, 14-1*, 15-1*
test tube holders	7	6-1
test tube racks	7	6-1*, 14-1
thermometers, Celsius	14	throughout
tripods (O)	7	14-1
tubing		
rubber or plastic (at least 6 mm inside diameter), 40-cm pieces	several	19-3
rubber or plastic (thin-walled), 5-cm pieces	7	12-2, 12-3
vials, 25 ml (or 2 dram)	14	10-1*, 10-2*
wire gauzes	7	12-2, 12-3, 14-1

Available from supply houses *Laboratory Materials: Consumable*

Material	*Amount*	*Investigations*
alcohol, 70% ethyl or isopropyl	500 ml	15-1
bromthymol blue (solution)	500 ml	6-1
calcium chloride, anhydrous	1 oz.	9-2, 12-2
cobalt chloride, 5% solution	50 ml	9-2
cotton, non-absorbent	1 roll	15-1
cotton (or foam) plugs	60	10-1, 10-2, 14-1, 15-1
cover slips	1 box	10-1, 14-1
filter paper		
strips, 2 cm x 8 cm	14 pieces	6-2 (AP)
disks, 10-cm diameter	120 pieces	9-2, 11-1, 11-2, 11-3, 15-1
Humidity Indicator Cards	7	9-2, 12-2

Material	*Amount*	*Investigations*
methyl cellulose	2 ml	10-1
nutrient agar	120 g	15-1
nutrient broth	120 g	15-1
Petri dishes, plastic	60	9-2
phenylthiocarbamide (PTC paper)	28 strips	3-2
*p*H paper	28 strips	19-1
sodium hydroxide	150 pellets	6-2
sodium propionate	10 g	14-2
sodium sulfite	100 g	19-4
sulfuric acid		
5%	100 ml	19-4
concentrated	250 ml	11-1
tubing		
glass or clear plastic (at least 6-mm bore)	2–3 metres	9-2*
thick-walled capillary (0.5 to 1.0 mm bore)	10 metres	6-2, 12-2*, 12-3

Available in the community *Reusable*

Material	*Amount*	*Investigations*
animals		
to observe	4	2-3
test	7–14	6-2, 9-1, 9-2
bathroom scale (O)	1	5-1, 5-2
blindfolds	14	8-1
bulbs, 8 watt	6	9-2
clothespins, spring type	60	19-2*
containers		
clear plastic shoe box	28	9-1*, 14-3
dishpans or buckets	15	3-2, 12-2
gallon jars	4	19-3
sampling jars (litre size)	28	7-1, 15-1, 19-1*
shallow pan	4	19-3
electric heating tape	1 roll	12-2
electric fan	1–2	12-2
flashlights	several	9-2
flowerpot, unglazed	1	8-3
goldfish	16	7-1
hot plate (O)	1	15-1
knife	1	12-2
lamps		
incandescent	3–4	7-1, 12-2
fluorescent	at least 1	7-1, 11-3, 12-2
light meter (O)	1	12-2
noisemakers (clickers)	16	3-2
paint brushes, small	several	9-2
paper punches	several	10-1, 10-2
pictures	4	3-3

Material	*Amount*	*Investigations*
pin sockets for 8-watt light bulbs	6	9-2
plants, to observe	4	2-3
pressure cooker or oven	1–2	15-1
rodent (mouse, hamster, or gerbil) (O)	2	8-3*
scissors	28 pair	throughout
sponges, large	6	9-1*, 12-3
tape recorder	1	2-4 (O), 3-3

Available in the Community *Consumable*

Material	*Amount*	*Investigations*
biscuits	8	14-2 (AP)
bleach, liquid chlorine	1 bottle	15-1
cardboard		
pieces	35	3-2, 3-3
sheets	14	8-1
cartoons or comic strips	28	2-2
cellophane (red, blue, green, and yellow)	1 roll each	9-2, 10-2
construction paper, black	50 sheets	4-4 (O), 8-1, 10-1, 10-2
cotton balls	small box	9-2, 10-1
cotton swabs (15 cm long)	several packages	15-1
food coloring (or washable ink)	1 bottle	6-2
garbage, assorted		14-3
garlic	1–2 cloves	15-1
glucose-analysis paper (Tes-tape)	28 pieces	1-2
glue (or rubber cement)	1 bottle	8-1
graph paper (centimetre)	150 sheets	5-1 (O), 6-2, 8-1, 8-2, 20-1 (O)
hamburger	¼ lb.	14-1
ice cubes	several trays	7-1, 9-2
map of your community	1	19-1, 19-2
nylon, 20–30 cm squares	12–24	15-1
oatmeal (or bran)	1 box	9-1
onions	6	9-2, 15-1
paints, bright colors	4–5	9-2
peas, dried split (O)	small bag	10-1
peat moss	small bag	9-1
petroleum jelly	1 jar	6-2, 12-2, 19-2
plants		
assorted	28	19-4*
branches or tops	7–21	12-2*, 12-3*
one variety	13	12-1*
plastic bags, clear		
food storage size	35	12-1*, 19-4*
sandwich size	25	11-1*, 11-2*, 11-3*, 12-1*

Material	*Amount*	*Investigations*
plastic cement	several tubes	9-2
plastic sheeting, black	3–5 square metres	9-2, 11-3
plastic wrap, clear	2–3 rolls	9-2, 12-2, 14-3
plywood, $\frac{1}{4}$ inch (or styrofoam sheets)	1 square metre	9-2 (AP)
poster board (O)	several sheets	2-4
potatoes, whole white	6	9-2
roots (such as carrots, horseradish, parsnips, and dandelions)	several	15-1
salt, non-iodized	1 box	9-2, 15-1
sandpaper, variety of grades	several sheets	9-2
soil	10 lb	14-3
straws	7–14	6-1
string	1 roll	6-2
sugar, granulated	1 small box	9-2
tape		
masking	1 roll	throughout
transparent	1 roll	throughout
toothpicks	1 box	10-1
tracing paper	100 sheets	1-1, 3-2, 3-3
vegetable matter, decaying		9-2 (AP)
vinegar	1 bottle	9-2
waxed paper	1 roll	10-2
wire, soft, 10-cm pieces (or wire ties)	7	12-1, 12-2, 12-3

Section Notes

1 Asking better questions

Behavioral Objectives

The students will learn

1. to ask questions that can be easily investigated.
2. to identify one part of a situation as the problem.

They will show they have learned

1. by asking questions that they can investigate themselves. (Extend Your View 1-1)
2. by asking questions that focus on the puzzling or unusual parts of an event. (Extend Your View 1-1)

Overview

The students identify properties of investigable questions. In Investigation 1-1, they analyze an optical illusion and work with a list of questions about it. In Investigation 1-2, there are two activities: One involves a chemical indicator; the other memory. Each situation contains some familiar aspects but will appear, on the whole, strange or illogical. To explain the activities, the students formulate questions that they can investigate for themselves.

Background

These Investigations introduce science as a mode of inquiry rather than a summary of conclusions. Questions have always been the major stock-in-trade for teachers, but unfortunately not for students. At all grade levels the student is bombarded with questions, and asked to recall isolated bits of information someone else thinks are interesting or important. Questions are also frequently used to direct the students along pathways completely predetermined by the teacher or the text. These traditional uses of questioning reduce the likelihood that a student will ask questions he can try to answer himself.

You and the Environment often allows the student to determine how to proceed with an Investigation. In many Investigations, the students ask their own questions and then design an experiment to find the answers. In Investigations 1-1 and 1-2, they learn just what kinds of questions can, in fact, be investigated.

Investigation 1-1
What is a useful question?

Most students should be able to gather data without much assistance. Let them ask and answer the questions about the optical illusion by themselves. You will short-circuit the development of inquiry skills if students find they can depend on you for answers. However, you can guide them by suggesting that they look at the questions for clues about what to do or look for. If the students are stumped by a question, suggest that they come back to it later.

Activity time: 15–30 minutes

Materials (individual):
56 sheets of tracing paper
28 metric rulers

Preparation
Some students may wish to investigate Question 5. You can prepare and have available five to ten copies of the variation of the basic figure suggested in the question.

Discussion
When discussing the questions, avoid distinguishing types of questions (such as the "why kind," the "general kind," or the "vague kind"). Instead, concentrate on the behavioral issue: Can the question be investigated as it now stands?

Questions 2 and 7 are the kinds of questions that students are most likely to ask when confronted with an unfamiliar situation. They are important questions; in fact, they may cause all the others to be asked.

But students often stop after asking general questions and wait for the teacher to answer these questions, instead of pursuing the issue on their own. It is not the students' fault, but the "fault" of the questions. These general questions cannot be resolved until many more specific questions are asked and answered.

Question 6 appears to be investigable—it asks for a "yes" or "no" answer. But the knowledge and techniques for experimentally obtaining data are too sophisticated for your students. Answers to this question will be guesses.

All other questions are investigable by students. They hint at or describe some means for obtaining specific answers. Question 4 requires that other people be consulted. Question 3 can be tested but the answer is not helpful for understanding why the lines appear curved. A better question might be, "Would the lines still appear curved if they were shorter or longer?"

Analyzing data

The discussion questions will have led students to see the role of the background in causing the lines to "bend." Some students may want to know why this is so. Suggest they write the question in their notebooks and try to answer it after they study perception. If new questions are asked about the illusion, suggest that the students try to answer them.

For your own information, this optical illusion is based on a divergence-convergence principle. It is impossible to look at anything apart from its surroundings. This is especially true of a geometric figure. Your eyes are led outward from the intersection point along the diverging lines on the page.

In the part of the figure where many lines cross in a small area, the effect is strongest. That is the central section. Near the outer edges of the figure, fewer and fewer diverging lines are contained between the parallel lines. The parallel lines seem to come back together at the ends. The bowing effect increases as the number of diverging lines increases. If you use a figure with half as many lines, the effect is lessened.

Investigable questions have at least these common properties. The questions should

1. focus on specific parts of a situation rather than on the whole.
2. ask for specific answers such as "yes" or "no", number, or amount.
3. focus on the strange or puzzling parts of situations.
4. Give hints or directions about what to do to find answers for yourself, instead of going to other people or books. (Personal interviews and library research are valuable sources of data, but at the beginning of this program direct research is emphasized.)

In the next few weeks, review the list with students whenever necessary. They will discover that their ability to ask investigable questions will be useful in future Investigations.

Investigation 1-2
Asking questions about people

Have the whole class participate in each activity to provide a larger quantity of data on the "test paper" and the "memory words." Then the class can divide to analyze the activities.

Activity time: 30 minutes

Test paper

Materials (individual):

28 pieces of glucose-analysis paper such as Tes-Tape ("test paper"), about 3 cm long

Tes-Tape is available in most drugstores. It is often used to indicate the presence of simple sugars, such as glucose, in urine.

Results

Some "test papers" will change color while others will not. It depends on the amount of sugar in the saliva. Color changes are more likely to occur soon after a person has eaten something. To insure both positive and negative responses, test your saliva last. If no one gets a color change, chew a piece of gum (not sugarless) before testing. If all tests are positive (highly unlikely), rinse your mouth with water before testing. You could also use "test papers" showing positive and negative responses from another class. Used "test papers" can be saved by placing them between pieces of transparent tape.

Memory words

Materials (individual):

14 copies of each list of "memory words"

Preparation

Make 14 copies of each list of memory words. Do not change the order of words in the list that contains the organizer, "BASKETBALL." The first letter of each word should be capitalized to draw attention to the organizer. Give half the students copies of one set and the rest copies of the other set. Make sure the students are unaware that there are two lists.

Behave	Listen
Almost	Kidnap
Street	Animal
Kidnap	Behave
Empty	Travel
Travel	Lonely
Breath	Breath
Animal	Street
Lonely	Empty
Listen	Almost

Results

In almost all cases, the group with the list that contains the organizer scores higher.

Extend Your View 1-1 How can this be?

Students usually ask about a number of factors. They may want to know the car's weight, the amount of surface area between the man's abdomen and the tire, whether or not the man is in pain, and if there is a hidden support. Your students will no doubt question a number of additional factors.

With three wheels on the ground, the man would have to support only a portion of the car's weight. This weight would be distributed over a large area of his abdomen, not concentrated on a single point. It would appear that a man with strong abdominal muscles can support such a weight. Do not try to duplicate this setup with your own volunteer. The photograph was rigged. Bricks were placed under the axle.

References

Kuhn, Thomas S. *The Structure of Scientific Revolutions,* 2nd ed. Chicago: University of Chicago Press, 1970. (Paperback) An examination of the development of science as a process in which one set of shared concepts replaces another. The author makes the analogy between scientific revolutions and natural selection.

Page, Chester H. and Paul Vigoureux, eds. *The International System of Units (SI).* National Bureau of Standards Special Publication 330, 1972. A basic reference on the metric system.

2 Making observations and inferences

Behavioral Objectives

The students will learn	*They will show they have learned*
1. to make better observations.	1a. by using more than one sense to make observations. (Extend Your View 2-1)
	1b. by recording their observations clearly. (Extend Your View 2-1)
	1c. by making quantitative observations whenever possible. (Extend Your View 2-2)
2. to make inferences.	2a. by making inferences from quantitative data. (Extend Your View 2-3)
	2b. by making inferences about an unfamiliar situation. (Extend Your View 2-4)
3. to distinguish between observations and inferences.	3. by dividing a list of statements into observations and inferences. (Extend Your View 2-5)

Overview

The students will observe, infer, measure, and specify procedures for making quantitative observations of living things. They will gain experience in making inferences and distinguishing them from observations. The Investigations are arranged so that one skill is developed at a time.

In Investigation 2-1, the students make observations about other students. In Investigation 2-2, students identify what inferences are needed to understand cartoons and comic strips. In Investigation 2-3, students practice making observations and inferences about less familiar organisms. In Investigation 2-4, students develop procedures for making quantitative observations of people.

Background

Scientists use both observation and inference. However, experiments are designed to collect observations *only*. The observations are often used to make inferences or test hypotheses. Making hypotheses will be developed later in this unit.

The distinction between "observation" and "inference" is usually not difficult to make. In a strict sense, observations are pure sense data: sight, touch, smell, sound, and taste, or some combination of these. Inferences go beyond immediate sense data. Inferences are derived by reasoning or implication from the available evidence.

Whenever a discussion of "inference versus observation" is pursued in depth, one eventually comes to the point at which *all* observations seem to be inferences. For instance, you say that you "observe" a student sitting in a chair. From an extreme viewpoint, you are only "inferring" his presence by processing certain impulses from your optic nerves. For this course (and, indeed, for most of science at all levels) it will be sufficient to agree that an observation is immediate sense data. An observation is what most people of a common culture would agree they were witnessing if put in the same place as the observer.

Another concept that is related to observations and inferences is perception. Perception is introduced in the next set of Investigations, "Perceiving the environment." Perception involves both sensory data and past experience. Immediate sense data is processed against a backdrop of past experiences.

Investigation 2-1
What can you observe about people?

You could begin by asking the class to describe a person everyone knows, such as the school principal or a public official. Ask for descriptions that would give a stranger an accurate picture of the person. Do not immediately accept or reject any contribution, but question each one to make the student think twice about the accuracy of the statement. For example:

Student contribution: "X has big ears."
Possible response: "Big compared to what?"
Student contribution: "X wears nice clothes."
Possible response: "How are nice clothes different from those that are not?"

After X has been described, ask for a volunteer to describe someone else who is familiar to the class. Let the volunteer complete his description; then ask the others what important features were left out. Classmates may be able to point out inaccuracies.

Conclude this initial activity by asking if the describer could have done a better job if he had deliberately made some direct observations in advance.

Activity time: 30–40 minutes

Analyzing data

1. Have one student read his observations to the class. See if the class can identify the subject. The ease of identification should increase with the number of observations and with more detailed observations.
2. Most humans are highly dependent on sight. They are likely to ignore their other senses until prompted.
3. Random observations might leave out many characteristics. One could carefully look at a classmate from head to toe or observe appearance first, then behavior. Stress the importance of a systematic approach. Using almost any deliberate plan, one would make more observations than by haphazard observation.
4. Some observations will, in fact, be inferences. You could use these "observations" to begin discussion of Investigation 2-2.

Investigation 2-2
What can you infer from a comic strip?

Cartoonists are usually skillful in presenting a situation with minimal information. The reader must make inferences to make the cartoon seem meaningful or humorous.

There are many techniques used to abbreviate a description. The words a character is thinking may be circled in a different way from spoken words. You can often infer the amount of power a character has by his size. Personality types can be indicated by clothing or by posture.

Sometimes a character will refer to a current event indirectly by word or by action. A certain gesture or phrase may be the unmistakable trademark of a well-known public individual. In serialized comic strips, it is often possible to infer the content of the previous day's strip. This is an easy inference to check.

Activity time: 30–40 minutes

Materials (individual):
28 cartoons or comic strips

Preparation

Have the students bring a cartoon or comic strip from their newspapers. You may wish to include cartoons from comic books. Cartoons from editorial sections and single cartoons from magazines are also suitable.

If you do not limit the source of cartoons, be prepared for some off-color examples. Have a few extra cartoons available for students who forget to bring one.

Analyzing data

1. An observation is data collected by our senses. An inference involves reasoning.
2. Some students may make different inferences from the same cartoon. An appreciation of some cartoons demands previous knowledge or experience.
3. An inference can be supported by further evidence. For example, inferences made about serialized comic strips can be checked by looking at earlier strips. It is also possible for an inference to be rejected on the basis of further evidence.
4. Some students may miss the point of cartoons, especially cartoons that require prior knowledge to make valid inferences.

Investigation 2-3
Observing other living things

In this Investigation, do not instruct students to make quantitative measurements. However, materials for making such measurements should be available. Some students will take the initiative. The difference between quantitative and qualitative observations is brought out in the Analyzing data section.

Activity time: 30–40 minutes

Materials (class):
2 pan balances
4 plants
4 animals
8 metresticks
8 magnifying glasses
Suitable organisms include potted plants, radish seedlings, corn seedlings, guinea pigs, hamsters, frogs, and earthworms.

If enough materials are not available, a few students might do the Investigation, with input from the rest of the class.

Investigation 2-4
Making quantitative observations

Many characteristics of living things do not seem, at first, to lend themselves to quantitative observation. Many advances in the biological sciences have resulted from the invention of new ways to quantify previously qualitative observations. An example is the invention of methods to measure the electric activity of muscles, nerves, and the brain.

In this Investigation, students will develop ways of measuring some human characteristics. Through this experience they will gain an understanding of some of the problems in making biological measurements. They will become aware of variation in data and learn to express this variation in data as the range. The data generated in this Investigation can be used again in Investigations 5-1 and 5-2.

Activity time: 2 class periods

Materials (groups of 3 or 4):
clock or watches with second hands
metresticks and metric measuring tapes
tape recorder
magnifying glasses
poster board and marking pens

Students should design their activity to fit available equipment. Students could examine hearing differences by having subjects listen to tape recordings of an unfamiliar song or two conversations superimposed. The students would write down what they heard. Poster board and marking pens could be used to make eye charts similar to those used by optometrists.

Analyzing data

Most students should have been able to get quantitative data to help answer the general questions. The range was probably most useful with data on continuous variables such as height.

Extend Your View 2-1
Describing an animal

Materials (class):
small animal

Ideally this animal should be similar to, but not the same as, the one used in Investigation 2-3. For example, if a frog was used, now use a toad. If a hamster was used, now use a mouse.

References

Brown, Lewis S., "The Right Way to Walk Four-Legged." *Natural History,* November 1968. One example of the use of an instrument, a camera, to improve human observations.

3 Perceiving the Environment

Behavioral Objectives

The students will learn

1. that perceptions are based on data received by sense receptors.
2. that there are limits to the reliability of sensory data.
3. that perceptions are influenced by more than sense receptors.

They will show they have learned

1. by inferring that living things will have different perceptions if they use different sense receptors. (Extend Your View 3-1)
2. by using measurements to improve the accuracy of their perceptions. (Extend Your View 3-2)

3a. by using past experiences as well as sense data to analyze perceptions. (Extend Your View 3-2)

3b. by inferring how different people might perceive the same object or event. (Extend Your View 3-3)

Overview

These Investigations introduce students to the concept of perception. Investigation 3-1 is a reading exercise on how four organisms gather information about their environment. Investigation 3-2 consists of four activities concerned with the limited reliability of sensory data. Investigation 3-3 deals with the effect of experience on perception.

These Investigations should help students understand the origins of conflicting points of view. Since students are asked to express freely some subjective feelings, care should be taken that personal opinions are not rejected or ridiculed just because they are unique. These Investigations should also help students understand that people seldom if ever have identical perceptions, even when they are in general agreement.

Background

Many people assume that everyone perceives the world as they do. Some people further assume that the perceived world and the actual world are the same. Sense receptors supply a flow of information. But even properly functioning receptors do not furnish the brain with distortion-free windows to the external world. Significant differences between the perceived world and the actual world arise for several reasons.

1. The receptors we possess have limited ranges of sensitivity and only respond, for example, to a narrow range of sound or light waves. Also, we lack receptors for perceiving some kinds of stimuli such as magnetic fields.
2. Of all the information our limited senses do gather, we choose to be aware of only a small part, and sometimes transform even that. "We see only what we want to see." Optical illusions are particularly interesting phenomena. They persist in the eye of the beholder despite his knowledge of the facts. This is also true of some social stereotypes.
3. Sometimes we perceive properties that cannot be precisely measured, but still are important, for example, tastiness, sexual attractiveness, and ugliness.

One could think of a perception as an interpretation of current sensory input—a complicated interweaving of immediate and past stimuli.

Investigation 3-1
How do animals get information?

This Investigation emphasizes that different organisms receive different kinds of sense data. Students could be asked to read Investigation 3-1 out of class and be prepared to discuss the questions. An alternative is to start with Investigation 3-2. The last part of Investigation 3-2 is on determining the direction of sound and requires a good deal of floor space and quiet. As groups of students do that exercise, the rest of the class could go to the library to read Investigation 3-1.

Activity time: 40–50 minutes
Reading: 20 minutes
Discussion: 20–30 minutes

Discussion

To emphasize the role of sense data in building perceptions, allow the students time to imagine the perceptions of organisms with different sensory inputs.

Ask students to try listing the new perceptions they would have if they were rattlesnakes. They could map out the area around their desks according to which

objects give off the most and least heat. Or you could suggest that they pretend that they have sensitive heat receptors, and have them select the part of the classroom where they would be most comfortable. (Half could be warm-loving and half could be cold-loving.)

The female moth produces a sex attractant in glands located on the tip of the abdomen. She emits the attractant when she is ready to mate. The male moth has odor-receptor cells on his antennae. The male moth moves upwind toward the source of the odor (usually the female moth). The antennae of female moths do not respond to the sex attractant.

Consider possible analogies, for example, the use of bottled scents by men and women.

Imagining the environment *Gymnarchus* perceives is perhaps the hardest of the four examples, because people are not normally aware of electrical differences in their environment. You might want to talk about ESP or acupuncture as examples that might involve electric perception in humans.

Analyzing data

1. The information an animal can receive is determined by the kinds of sense receptor the animal has and how sensitive these receptors are.
2. These organisms either have different sense receptors or can detect stimuli that our receptors miss.
3. The snake associates warm objects with warm-blooded food. It may never have encountered an inanimate object before that was significantly warmer than its surroundings.

Investigation 3-2
How reliable are your senses?

This Investigation has four parts that lead students to question whether or not their sense data yield reliable information about the physical world. It may not be possible for each student to do all parts of this Investigation, since individual participation depends on available time, space, and materials. The smaller the student groups, the more likely that all the students will be personally involved.

The ability to taste

Activity time: 10 minutes

Materials (individual):
28 pieces of phenyl thiocarbamide (PTC) paper
Pieces one centimetre square are adequate.

Analyzing data
Data from this exercise demonstrates the range of ability to taste a particular compound. About 70 percent of the population will find PTC extremely bitter, while the remainder will not detect any taste. The ability to taste PTC is inherited, but for the purposes of the exercise, the emphasis should be on the varieties of sensory ability, not on the genetics.

How accurately can you see?

Activity time: 30–40 minutes

Materials (groups of 4):
7 pieces of tracing paper
7 pairs of scissors
7 pieces of cardboard or heavy paper
7 black felt-tip marking pens
7 rulers

Preparation
To save time, you could prepare the cutouts in advance.

Analyzing data
1. A–A distances are usually significantly longer than B–B or C–C distances.
2. The students will probably conclude that their ability to estimate lengths may be influenced by the shapes of the objects used.
3. The visual clues afforded by the converging points cause people to perceive the line as shorter than it really is. The opposite seems to be true for the diverging points.

Hot or cold

Activity time: 10 minutes

Materials (5 stations):
5 thermometers, Celsius
15 water-tight containers

Two of the containers should be large enough for a student to immerse one hand. The other container should be large enough for a student to easily immerse both hands at the same time. You could use pneumatic troughs, pails, or baking dishes.

Preparation
Set up as many stations of three containers as your equipment allows. Five sets would be ideal. One container should be filled with water at about 42°C, obviously hot but not hot enough to damage skin tissue. Most people can soon tolerate this temperature. A second container should have water at room temperature, or a little warmer (22–27°C). The third should contain water at about 10°C. At temperatures lower than this, it is quite painful to keep a hand immersed. Label the containers H, X, and C, respectively.

Analyzing data

The students will probably select the data collected with the thermometer. This data is less subject to human judgment and can be reproduced by other people. Students should conclude that their sense receptors for heat give relative data.

Determining the direction of sound

Activity time: 30–40 minutes

Materials (groups of 9):
2 clocks or watches with second hand (optional)
16 noisemakers (8 per group)

The variety store metal "clicker" or "cricket" is recommended. The sounds produced by the noisemakers should be as uniform as possible.

Instructions

This activity will require a lot of space. You may have room for only one or two groups at a time. Groups should be well separated so that clicks from one group do not confuse the responses in another. Do this activity with as little outside noise as possible. To minimize surrounding sounds, one group may collect data while the other students observe.

Analyzing data

The data should show that sounds emanating directly in front of or in back of the observer are the most difficult to locate. These signals reach both ears at the same time. A sound coming from the side of an observer reaches one ear more rapidly than the other. The difference in reception time is used by the brain to identify the direction of the sound source. Obstacles between a sound source and the ears could also confuse direction estimates.

Discussion

Conclude Investigation 3-2 by summarizing the findings on sensory reliability. All students now have data that indicates that our senses do not provide exact information on the physical world. Much of the sense data that we get is relative. Hot or cold, light or dark, loud or faint—these are subjective judgments. To reduce subjectivity we use a variety of measuring instruments to supplement our senses.

Investigation 3-3
How does experience affect perception?

This Investigation represents the next logical step in building an understanding of perception. Perception is now to be considered as an active process, not the passive reception of sense data. There are three activities in this Investigation. They support each other, and each student should participate in all three.

What don't you hear?

Activity time: 30 minutes

Materials (class):
tape recorder

Analyzing data

An analysis of the tape will provide background for a discussion of selective perception. Students should become aware that they sometimes subconsciously exclude certain signals. For example, students who were actively involved in the discussion may only have heard the individual speakers; students who were paying less attention may have heard more of the outside sounds. They may even have blocked much of the discussion.

How do we perceive sizes?

The perception of size is a complex phenomenon and cannot be comprehensively considered in this exercise. However, students can understand the use of past experiences in making some size determinations.

Activity time: 20 minutes This activity could be done at home.

Materials (individual):
28 pieces of tracing paper
28 pieces of cardboard or heavy paper
28 pairs of scissors (fewer could be shared)

Analyzing data

The two small paper cars are identical, but as the student moves them, they appear to change size. Some psychologists say such illusions result from a subconscious adjustment. Because of experience, one automatically expects objects to diminish in size as they become more distant. The road illustrated may provide enough distance clues for the mind to make this habitual adjustment. We then compensate and the farther object appears larger than it actually is.

Visual estimates of size are influenced by the nature of the object being viewed and the background, even when people know they are dealing with an optical illusion. It is possible to get an absurd perception when clues habitually used are absent or in conflict.

Does everyone perceive in the same way?

Here the students are shown a series of illustrations that can be interpreted in many ways. The objective is to emphasize that varied perceptions of the same stimulus are not only acceptable but inevitable.

Activity time: 20 minutes

Materials (class):
4 pictures
overhead projector (optional)

The pictures you choose should evoke many different perceptions. Impressionist and surrealist art works well because people try to explain "unreal" images in "real" terms. Realistic art is also suitable, especially if the picture is full of so many different things that a ten-second exposure would not be nearly enough time to comprehend all of it. Pictures can come from books, magazines, and jigsaw puzzle box lids as well as posters. Color reproductions are recommended.

Suggestions
Cézanne—*Mont Sainte-Victoire Seen From Bibemus Quarry*
Chagall—*I and the Village*
Dali—*Apparition of Face and Fruit Dish*
Gandhara—*The Fasting Buddha*
Japanese—*Jigoku Zoshi* (Hell Scroll)
Mondrian—*Composition with Red, Blue, and Yellow*
Picasso—*Three Musicians*
Bull's Head
Guernica
Ambroise Vollard
Van Gogh—*Wheat Field and Cypress Trees*

In addition, these sources are useful: Picasso (particularly his cubist period), Cezanne, Dali, Escher, Monet, Bruegel, also Chinese or Japanese art, and 20th Century Sculpture. Most of these suggestions are in:

Gombrich, Ernst H. *The Story of Art,* 12th ed. Staten Island, New York: Phaeton Press, 1972.
Janson, Horst W. *History of Art,* rev. ed. New York: Harry N. Abrams, Inc., 1964.

Instructions
First project each illustration for ten seconds. Allow a pause of two minutes between the pictures. During this time turn on the lights so the students can record their responses. Then show all the pictures again. Keep each one on the screen as long as student discussion warrants. The text calls for a projection of the pictures. However, if you have large posters, you may present them in front of the class for ten seconds. You could also use slides.

Analyzing data
1. The first time the pictures were shown, the students probably focused on and recalled different details.
2. After the second viewing, the students were probably able to agree on the basic content of the pictures (except for those students with perceptual limitations such as colorblindness).
3. It is less likely that there was general agreement on the meaning of the pictures. "Mood" might be easier to determine than "message."
4. The meaning of a picture is subjective—many art critics have disagreed on the interpretation of an individual work of art. The length of a line can be verified with a measuring device. It is easier and more useful for people to reach agreement on measurable factors.

These points should be considered when you summarize Investigation 3-3.

1. Individual perceptions are based on the "best" interpretations that people can make from the sense data available and their past experience. These perceptions may change with new sense data.
2. In some cases our "best" perception of an object or situation depends on how we want to perceive it.

References

Dundes, Alan. "Seeing is Believing." *Natural History,* May, 1972. American speech patterns reveal a cultural preference for the sense of sight.

Kagan, Jerome and Havemann, Ernest. *Psychology: An Introduction.* New York: Harcourt Brace Jovanovich, Inc., 1972. This discussion of perception includes a number of suggestions for activities.

Lissmann, H. W. "Electric Location by Fishes." *Scientific American,* March, 1963. Discusses the mechanism for electric perception in *Gymnarchus niloticus.*

McCormack, Alan J. "ESP Believe it or Not!" *Science Activities,* December/January, 1974. Some simple ESP experiments for the classroom, including the use of Rhine cards.

Novick, Alvin. "Echolocation in Bats." *Natural History,* March, 1970. Summary of findings in the field of bat-orientation.

Schneider, Dietrich. "The Sex-Attractant Receptor of Moths." *Scientific American,* July, 1974. A detailed description of experiments with the antennae of silk moths.

"Serpentine Snooperscope." *Chemistry,* February, 1974, p. 21. A brief discussion of heat sensors in snakes.

Teuber, Marianne L. "Sources of Ambiguity in the Prints of Maurits C. Escher." *Scientific American,* July, 1974. Describes the close connection between Escher's art and early experiments on visual perception.

4 Organizing data

Behavioral Objectives

The students will learn

1. to perceive patterns in a collection of items.
2. that there are many ways to classify the same collection.
3. that the boundaries between categories in a classification scheme are often difficult to determine.
4. that most organisms can be classified as plants or as animals, though some have properties common to both groups.
5. that rearranging quantitative data can reveal patterns.

They will show they have learned

1. by identifying which items fit a pattern they perceive. (Extend Your View 4-1)
2. by classifying a collection of objects in more than one way. (Extend Your View 4-2)
3. by deciding whether something is living or nonliving. (Extend Your View 4-3)
4. by inferring from its properties whether an organism is a plant or an animal. (Extend Your View 4-4)
5. by organizing quantitative data to answer a question. (Extend Your View 4-5)

Overview

In these Investigations, students learn to perceive patterns and use these patterns as a basis for organizing data. Sometimes the organized data also reveals unexpected patterns. In Investigation 4-1, students look at a series of five figures to determine which one does not fit the pattern the other four follow. In Investigation 4-2, students look for patterns that they can use to classify a collection of items.

In Investigation 4-3, students study collections of living and nonliving things to discover the properties that distinguish one category from the other. They also discover some differences between plants and animals. Finally, in Investigation 4-4, students collect data on heartbeat rates and organize the data according to the average and the range. They also make bar graphs.

Background

People in general and scientists in particular try to make sense of their world. Often there is a large amount of data that must be organized before it is useful. Classification is one way to organize information. It is often easier to consider a small number of categories than a large number of individual items. It is more efficient to learn that mammals as a class can regulate their body temperature than it is to learn, one at a time, that humans, dogs, elephants, and horses perform this function.

When items are organized, the organization is usually based on some property of the items. This might be the first letter of a last name or the ability of an organism to regulate its temperature. Sometimes the property on which a classification scheme is based may have only two values, all or none. For example, if someone asks you if you are a Canadian citizen, a "yes" or "no" answer will determine into which group you will be classified.

Classification schemes are not immutable. They are conveniences, subject to revision or rejection in favor of better schemes. Because classification schemes are human constructs, problems sometimes arise at the boundaries between categories. For example, mammals are animals that are able to regulate their body temperature. Mammals also bear live young. The platypus has many properties of mammals, but it does not bear live young. It is still classed with mammals even though it does not fit all the criteria for mammals.

Investigation 4-1 Perceiving a pattern

This activity ties together the ideas of perception and pattern recognition. Students look at a series of figures and determine which one of the five does not belong in the group. To do this they must perceive a pattern that four of the figures follow.

Activity time: 20–30 minutes The students could gather data for homework.

Materials (individual):
drawings on page 49

Possible answers

1. a is an even number; b, c, d, and e are odd.

   b is made of only straight lines; a, c, d, and e have curved lines.

   a and e are shapes with closed loops; b, c, and d are open figures.

   a, c, and e are made of only curved lines; b and d have straight lines.

2. b is made with only a curved line; a, c, d, and e have straight lines.

   c is not a Roman numeral; a, b, d, and e are.

   c has an enclosed area; a, b, d, and e are open figures.

   c and e are vowels; a, b, and d are consonants.

3. d does not have a volume that can be filled; a, b, c, and e do.

   a, c, and e are serving pieces; b and d are cooking utensils.

4. a has one dot pointing away from the center; b, c, d, and e have all dots pointing toward the center.

   c, d, and e are the same figure positioned differently (middle one at 90° to others); a and b show different angle relationships.

5. e is not footwear; a, b, c, and d are.

   a and e are rainwear; b, c, and d are not.

6. c is the only winning ticktacktoe board: a, b, d, and e are losing boards.

   c and d have four O's; a , b, and e have five O's.

   a and b are identical arrangements rotated 90°; c, d, and e are different.

7. c is a mirror-image of the rest of the symbols; a, b, d, and e are the same symbol positioned differently.

   a, c, and e are positioned up and down; b and d are positioned sideways.

8. b is a land vehicle; a, c, d, and e are water vehicles.

   b, c, and d are power vehicles; a and e are not.

Analyzing data

1. Some of the series have more than one obvious pattern. Some students may perceive patterns other than the examples given. There are no right or wrong answers; there are just some answers that seem more obvious.
2. The students probably considered the structure of the figures and, in some cases, the function of the items. Past experiences often influence perception, for instance the recognition of odd and even numbers or of Roman numerals.
3. See the Possible answers section.
4. Classification schemes could be devised in which the items are grouped two, two, and one. This would require properties that have at least three values.

Investigation 4-2
Patterns help to organize

Students look at a collection of nonliving items and classify the items into groups. These groups will be based on properties of the items. In Investigation 4-1, students classified a set of figures with a controlled number of properties. In this activity there are more properties to consider and no specific patterns to look for. For these reasons there will be a larger variety of classification schemes.

The stamps on pages 52–53 can be used to introduce or summarize this activity. Traditionally stamps were collected by country of origin, but now a subject or thematic approach is often used. The basis for grouping the stamps will vary. It may be properties of the organisms on the stamps (number of legs or relative weight) or the physical properties of the stamps (size, denomination, or ratio of length to width).

Activity time: 30–40 minutes

Materials (individual):

Ideally there should be one collection for each student. Each collection should contain between 8 and 30 items. Use objects that are easy to collect: buttons, coins, marbles, paperback books, nails, laboratory apparatus.

Try to arrange the collections so that some can be grouped by function as well as by physical characteristics. Also try to include collections that work well with more than one sense: a collection where some objects make a sound and some do not, a collection where some objects are soft and some firm, some rough and some smooth.

Preparation

To help students report their groups accurately, label each object in each collection with a number or letter. Use a felt-tip marker, or attach a label. Do not use names on the labels.

Analyzing data

Students should discuss their classifications. Any grouping system that works is acceptable. There may be reasons for thinking one scheme is better than

another, but even here, the possible purposes of a scheme must be considered.

There can be one item in a "group," but if all groups have but a single item the classification system has achieved nothing.

Investigation 4-3
What does "alive" mean?

In this activity students classify items as living or nonliving, plant or animal. In contrast to the previous Investigations, this activity asks students to group their items into predetermined groups, groups with which they are familiar in an informal way. Most students already "know" how to recognize living things, although they might not know the basis for their decisions.

This activity can be introduced by directing the attention of the class to a living animal, for example, a goldfish. While feeding the fish ask, "Is this alive? What makes you think so?" Students should have little difficulty responding to these questions.

Suggest that each student develop a list of the properties of living things. Some typical responses will be: it grows, it reacts, it eats, it reproduces. The activity can then be used to validate the properties on the students' lists.

Scientists agree that living things possess certain interrelated characteristics. The most distinctive are: growth, reproduction, response to their environment, and capacity for self-maintenance. To support these life processes, a supply of materials from the environment is necessary. The materials and energy are used in internal chemical activities called metabolism.

You can usually obtain direct or indirect evidence of life by observing an organism. But it is difficult to infer whether or not something is alive if it does not display obvious activity. This is the case with dormant structures such as a seed or cocoon, and parts of organisms such as the stalks of plants. In these cases, further evidence must be gathered. For example, seeds can be placed under conditions favorable for germination. You cannot be certain the seeds are alive until you see them grow.

In general, to properly classify some organisms as living or nonliving requires a deferred judgment. Some of the organisms suggested will need special treatment before they will show any signs of life. While waiting for results, go on to the next Investigations. Conclude this activity before asking students to do Extend Your Views 4-3 and 4-4.

Activity time: 40 minutes Additional time may be needed to investigate some of the dormant organisms.

Materials (class):
Provide as many of these items as possible.

- Animals
  - fish
  - snails
  - insect eggs, such as ant eggs from fish food
  - dried brine shrimp eggs
  - chilled earthworms
  - hydra
  - insects or other arthropods, some chilled
  - moth cocoons and praying mantis egg cases
- Plants
  - some with conspicuous stems and leaves, aquatic and terrestrial
  - Spanish moss and other epiphytes (some lacking obvious stems or leaves, such as mosses, horsetails, or lichens that resemble plants)
  - potatoes or sweet potatoes
  - large seeds: a coconut if available, corn seeds, or an avocado pit
  - flower bulbs
- Organisms not obviously plant or animal
  - algae, especially brown or red algae
  - mushrooms, fully grown or available as spawn or mushroom-growing sets
  - bread and fruit mold
  - lichens
  - yeast
- nonliving objects
  - dried branches, leaves, or seedpods
  - fossils
  - spider web
  - hair
  - hen's egg (Only fresh, fertilized eggs are alive.)
  - rocks, glass, or other inorganic matter
  - empty shells from crustaceans and mollusks
  - crystal gardens

If real materials are absolutely not available, the pictures on pages 54–55 may be used in this activity. The pictures can be used much more effectively if they provide the basis for discussion before or after students work with collections of real things.

Preparation
Students can sprout potatoes, sweet potatoes, and avocado pits in a glass of water. Support the pits or potatoes on the rim of the glass by sticking toothpicks into them as shown in Figure 4-1T. Keep them in a warm, dark place until roots appear.

Students can put pieces of bread and ripe fruit in a moist, warm place. Mold organisms will appear in a few days. It is better to use brown or homemade bread because some white breads contain preservatives that retard the growth of molds.

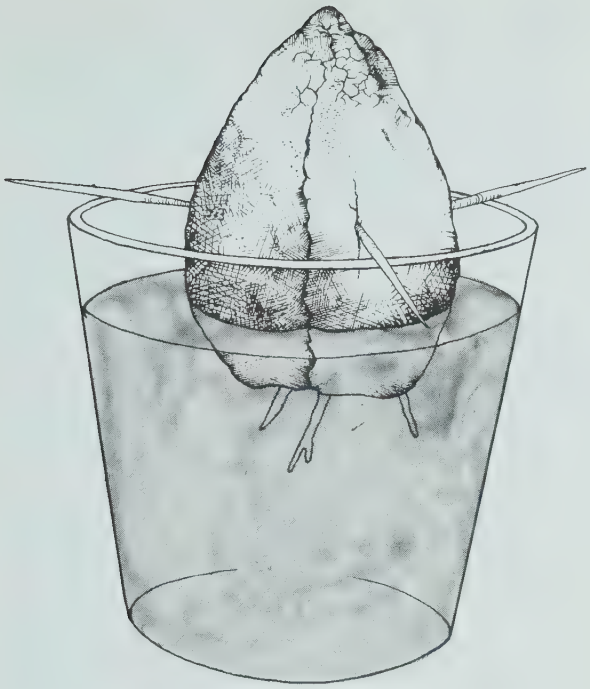


Figure 4-1T

Students can observe a few grains of yeast through a hand lens or under the low power of a microscope. (If students have not previously used a microscope, have them work with the program on the microscope, Appendix D.) They can also look at grains of sand at the same time to compare them to the yeast. Students can grow yeast by sprinkling some into fruit juice. The next day, they can observe appearance and smell.

Students can easily grow crystals. For directions, see:

Holden, Alan and Singer, Phyllis. *Crystals and Crystal Growing.* Garden City, N.Y.: Doubleday Inc., 1960.

Discussion

Very likely students' responses will be a mixture of observations and inferences based on past experience. Ask them to examine their lists and identify their inferences. Some inferences, for example, that fish reproduce, could be verified in time through observation. Class discussion of the inferences should lead to general agreement to keep some on the list and reject others. If students suggest ways to verify inferences, encourage them to carry out their plans.

Do not supply the class with prepared lists of properties. Ask your class to prepare such lists. Then ask the students to name or describe organisms that would not fit their descriptions. When the students seem content with their list of properties, present for discussion some of the unclassified and inanimate items suggested in the Materials list.

Analyzing data

It is difficult to distinguish between living and nonliving things on the basis of a single property. If being able to move is suggested as evidence of life, you might remark that airplanes, the hands of a clock, air, and water also move. If having a form or structure is suggested, you might note that lampposts and shadows have shape and size, while amoebas can change form. Growth may seem to be a property of living things only, but crystals and shadows grow, too.

Encourage students to challenge each other's responses in a similar manner. Properties should not be discarded just because an exception can be found. It should be made clear, however, that these are not properties of only living things, nor are they the only properties of living things.

Willing and thoughtful participation in the class's search for common properties should be considered as an indication of comprehension, especially since this is largely a discussion-oriented Investigation.

Investigation 4-4
How fast does your heart beat?

There are a number of properties such as height, weight, and heartbeat rate that have a range of values for any group of subjects. It is important that students understand how to organize and interpret such data to look for patterns.

Heartbeat rates are used because they do not usually cause embarrassment as height or weight might. Rates are quickly and easily gathered. If students are concerned that their rates are "abnormal," assure them that a range of rates is normal. There is no absolute normal rate.

Activity time: 40 minutes For an easy comparison of data, the students could agree on a standard method and use that method on all subjects. If the students use different procedures, it may be more difficult to compare the data, and more time may be needed.

Materials (groups of 2):

clock or 14 watches with a second hand
14 pieces of construction paper (optional)

Analyzing data

The class data will not make much sense at first glance. The data can be organized, then examined for patterns. Organization should be based on properties of the persons involved (age or sex, for example). Then the range or average can be determined.

1. It would be unlikely that everyone reported the same heartbeat rate. There will probably be some variation even with the same subject and method. The students will need to report average heartbeat rates.
2. The students would have to agree on a standard time interval before comparing data.
3. Students can compare observations made by different methods if the data is reported in the same units. However, alternate methods for measuring variables other than heartbeat rate can vary in the degree of accuracy.
4. The range of heartbeat rates may be as large as 50 beats per minute.
5. There will probably not be a significant difference in the averages.

5 Making and testing hypotheses

Behavioral Objectives

The students will learn	*They will show they have learned*
1. that a hypothesis is a prediction about the relation between two variables.	1a. by selecting properties that can be used as variables. (Extend Your View 5-1) 1b. by making a hypothesis about two variables. (Extend Your View 5-1)
2. how to judge the acceptability of a hypothesis.	2. by organizing data to decide if a hypothesis is supported or rejected. (Extend Your View 5-2)

Overview

In these Investigations, students learn to make and test hypotheses. They begin to synthesize the skills that were introduced in the previous Investigations: questioning, observing, inferring, perceiving, and organizing data.

In Investigation 5-1, the students make hypotheses about heartbeat rate and some other human characteristics. They organize their data by average and range to reveal patterns. Graphing can be used as an optional method for analyzing data. There is a program on graphing in Appendix C to supplement this Investigation.

In Investigation 5-2, students make and test hypotheses about reaction time. Using a metrestick, they indirectly measure the reaction time for each member of the class.

Background

These investigations introduce the concepts of variable and hypothesis. A discussion of variables is usually expanded to include dependent and independent variables. Unfortunately, people tend to confuse the two terms. The concepts, however, are important in making hypotheses and graphing.

The problem is reduced by introducing hypotheses as *if-then* statements such as: If a person is tall, then his heart will beat faster. The two types of variables can logically be named for their functions within the hypothesis. For this reason, *if-variable* and *then-variable* are used to help students learn the basic concepts. With increased proficiency, the student will probably drop this format in favor of a more direct statement such as: Tall people have faster heartbeat rates.

A hypothesis usually relates only two variables. One variable, the *if-variable*, is manipulated by the investigator. Any change in the second variable, the *then-variable*, is noted and attributed to the change in the *if-variable*. In graphing, the *if-variable* is usually placed on the horizontal axis.

Hypotheses are often suggested by perceived patterns. For example, Dr. Carlos Finlay once noticed that people who contracted yellow fever had been bitten by a certain kind of mosquito. This observed pattern led to a hypothesis explaining the transmission of yellow fever. Subsequent experiments by Dr. Walter Reed supported the hypothesis.

In more recent times, Dr. Robert Rosenthal noticed that the children who did poorly in school were often those the teacher expected to do poorly. When a teacher was told that a child was especially bright (regardless of his or her actual ability), the child performed better in the teacher's class. This tended to

support Dr. Rosenthal's hypothesis. However, not all investigators have had similar results and so the matter is still unresolved.

Analyzing data to test a hypothesis can be a complex process. Sophisticated statistical techniques are often used. Your students are obviously not familiar with tests of significance based on statistical probabilities. A less rigorous kind of analysis is called for. In these Investigations, graphing or comparing averages will be adequate.

No matter what level of data analysis is used, no data can ever prove that a hypothesis is absolutely true. Testing the same hypothesis in many ways and always obtaining supporting evidence increases one's confidence in a hypothesis. But if any evidence actually contradicts a given hypothesis, the hypothesis must be rejected—at least until someone shows that the evidence was inaccurate or unreliable. It is possible to speak of "accepting" or "rejecting" a hypothesis with these reservations in mind.

Investigation 5-1 What is a hypothesis?

The variables used in this Investigation are the same as the properties used in classifying. Students should be able to see that making hypotheses is an extension of classifying and looking for patterns. If some students have difficulty with hypothesis-making, have them mechanically construct hypotheses by using the *if-then* pattern. Emphasize that a hypothesis is a way of expressing a supposed connection between two variables so the connection can be tested.

In later Investigations, students will learn how to manipulate the *if-variable* and look for a change in the *then-variable*. Introducing this idea now may only confuse some students.

Activity time: 2 class periods
Data gathering: 40 minutes
Data analysis: 40 minutes
More time may be necessary if students need help with graphing. Less time may be needed if students have already gathered class data on a related property, such as height, in Investigation 2-4.

Materials (groups of 4):
data from Investigations 2-4 and 4-4, if available
28 pieces of graph paper (optional)
instruments to measure properties related to heartbeat, for example, metresticks, calipers, a scale

Analyzing data
If the sample is large enough, there should be a decrease in heartbeat rate as age increases. (From ages 7–12 the decrease is about 10 beats per minute.) Heartbeat rate is usually faster when the subject is standing rather than sitting or lying down. A sleeping subject would have a lower heartbeat rate. Exercise usually increases heartbeat rate noticeably. You may notice a correlation between heartbeat rate and height or mass. Since your class is a small sample, a relationship between heartbeat and another variable may not be apparent.

Investigation 5-2 Testing another hypothesis

In this Investigation, students are not measuring reaction time directly. They are measuring the distance the metrestick drops and inferring the time from this. Faster reaction times are indicated by smaller distances but they are not directly proportional.

To find the actual reaction time, use this formula:

$$T = \sqrt{2s/g}$$

where t is the time in seconds, s is the distance in centimetres, and g is the acceleration due to gravity (980 cm/s^2). This formula applies when the object starts from rest, and is accurate only for a fall of a few seconds.

You could demonstrate the need for an indirect method for measuring reaction time by trying to time the fall of the metrestick with a stopwatch. The reaction time of the person using the stopwatch would probably be longer than the intervals being measured (less than one second).

Bar graphs are limited to expressing data for one variable. They are useful for looking at trends. A line graph provides a useful way to examine a relationship between two continuous variables. Scattergrams can be especially useful for comparing continuous variables such as heartbeat rate, height, or mass. If data points are randomly scattered over the graph, there is no relationship between the variables.

Activity time: 2 class periods
Data gathering: 40 minutes
Data analysis: 40 minutes

Materials (groups of 2):
14 metresticks
data from Investigations 2-4 and 4-4, if available
other measuring instruments.

Analyzing data
1. Reaction time usually improves with practice.
2. The variable that makes the greatest difference in reaction time is sex. In general, women have slower reaction times than men.
3. Students could test this hypothesis. Reaction time will probably increase when hands are switched.
4. Students could also test this hypothesis.

6 Doing experiments

Behavioral Objectives

The students will learn

1. that a well-designed experiment includes a control.
2. that both plants and animals exchange gases with their environments.

They will show they have learned

1. by describing the difference between a poorly-designed experiment and a better one. (Extend Your View 6-1)
2. by using what they learn about respiration to predict the results of an experiment. (Extend Your View 6-2)

Overview

For the first time in *You and the Environment,* students will do experiments by themselves and learn about the need for controlling variables. In Investigation 6-1, the students obtain direct evidence that gas exchange occurs in both plants and animals. In Investigation 6-2, they do experiments on the rate of gas exchange in seeds and animals, using a simple respirometer. The emphasis is on doing experiments, not the chemistry of respiration.

Background

Ideally, an experimental design should keep all of the variables constant except the *if-* and *then-variables.* This makes it possible to associate effects with their causes.

It is often difficult, especially in the life sciences, to design experiments in which all the variables can be controlled. For example, snails in a tube of bromthymol blue solution might cause the indicator to turn yellow because of excretion, not respiration. You cannot stop the snails from doing everything but respiring while you run the experiment. Life systems are not collections of separable factors. You infer, and with good reason, that respiration causes the color change, but it would take a better experimental design to eliminate additional factors. On the other hand, it is relatively easy to set up a comparison, or control, (a test tube without organisms) to show the stability of the chemical bromthymol blue.

Investigation 6-1
Do aquatic plants and animals exchange gases?

Through respiration, organisms exchange gases with the environment. Gas exchange in plants includes both respiration and photosynthesis. Plants respire in the light, but at a lower rate than they photosynthesize. Photosynthesis is a complex sequence of reactions, some of which take place in the dark. But none of the reactions can take place unless the plant is periodically exposed to light. Therefore, a plant kept in prolonged darkness can only respire.

Respiration releases energy from the food that an animal has eaten. In simple terms, respiration may be summarized:

$$(CH_2O) + O_2 \rightarrow CO_2 + H_2O + \text{energy}$$

(CH_2O) stands for one unit in a carbohydrate chain. An organism, plant or animal, uses oxygen to release energy from starch or sugar. Respiration is analogous to combustion, but it proceeds in controlled steps. It provides an organism with a regulated energy supply.

It is easy to demonstrate gas exchange with aquatic organisms. The carbon dioxide they give off reacts with water to produce carbonic acid, which makes the solution more acidic.

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

This change in acidity can be shown by a chemical indicator. In this Investigation, bromthymol blue is used as the indicator. It is blue in basic solutions and yellow in acidic solutions. At an intermediate stage, the solution will appear green. The blue solution will turn yellow when carbon dioxide is produced.

If carbon dioxide is removed from an acidic solution by photosynthesis or boiling, the bromthymol turns blue again. Aerating the bromthymol blue may not allow the carbon dioxide to escape. It usually does not work in a test tube. In an Erlenmeyer flask the solution usually turns from yellow to dark green. Boiling will turn the solution from yellow to green to blue depending on the length of boiling.

Suggest that students check the temperature in the lighted area and in the closet at the beginning of the

experiment and the next day. Although unable to control temperature, they should be aware that any marked differences in this factor could affect their results.

Activity time: 45-60 minutes
Testing bromthymol blue: 10–15 minutes
Setting up test tubes: 10–15 minutes
Making the data table: 10 minutes
Observing and recording results: 15–20 minutes (the next day)

Materials (groups of 4):
500 ml bromthymol blue solution
7–14 soda straws
21 test tubes (16 × 150 mm) with solid rubber stoppers (#1)
7 test tube racks (or beakers)
7 test tube holders
7 burners
14 pond snails, small enough to fit into test tube
7 sprigs of Elodea (*Anarcharis sp.*) Try to make the sprigs fairly equal in size.

Preparation
To prepare a stock solution of bromthymol blue, mix 0.1 g bromthymol blue with a litre of distilled water. The stock solution may have to be diluted with more water, so that the organisms will be visible. If the solution looks yellow or green, add a trace of 10% ammonium hydroxide. Add one drop at a time while swirling the solution until the solution just turns blue. If you add more ammonium hydroxide, it will take more carbon dioxide to turn it yellow; it will be a less sensitive indicator. The solution is reusable and can be saved at the end of the Investigation. Keep the prepared solution covered to prevent carbon dioxide in the air from dissolving into it.

Test the solution by filling a test tube one-third full. Blow through a straw into the solution. The solution should change to green and then to yellow within a minute.

Alternate setup
The suggested concentrations of bromthymol blue will probably not harm Elodea or snails. However, if you or your students object to immersing snails or Elodea in bromthymol blue, you could put mealworms and bean sprouts on a cardboard platform in a closed container as shown in Figure 6-1T. The bromthymol blue would be in the bottom of the container, below the cardboard.

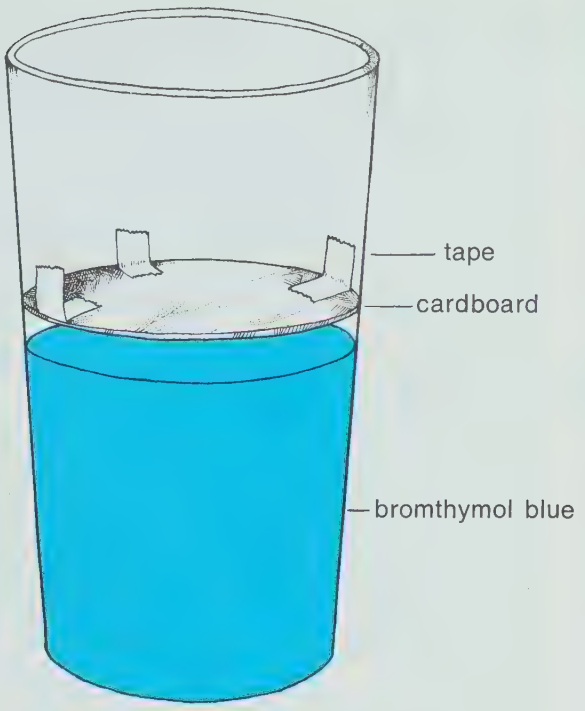


Figure 6-1T

Analyzing data

1.

	Tube	*Hypothesis*	*Color*
Light	A	If aquatic plants produce carbon dioxide in the light, then the blue liquid will turn yellow.	blue
	B	If aquatic snails produce carbon dioxide in the light, then the blue liquid will turn yellow.	yellow
	C	Does the blue liquid change color itself in the light?	blue
Dark	A	If aquatic plants produce carbon dioxide in the dark, then the blue liquid will turn yellow.	yellow
	B	If aquatic snails produce carbon dioxide in the dark, then the blue liquid will turn yellow.	yellow
	C	Does the blue liquid change color itself in the dark?	blue

2. You can infer that an organism is using oxygen if it is producing carbon dioxide. In the light the snails used oxygen but the plants did not seem to. (See detailed discussion in Background.) In the dark both the snails and the plants used oxygen.
3. Tube C did not change color in the light or in the dark. This means that light itself did not produce a reaction in the blue liquid. If the blue liquid had turned yellow, you would not have known whether light or the organism had been responsible.

Investigation 6-2
Measuring respiration

Measurements of air pressure are commonly used to indicate the occurrence of gas exchange. For every molecule of oxygen consumed by an animal or plant, about one molecule of carbon dioxide is produced. In a closed container, the total volume of gas hardly changes, although the amounts of oxygen and carbon dioxide do. But, if one gas is removed as quickly as it is produced, the change in the volume of the other can be determined. Generally, carbon dioxide is removed because there are several common chemicals that readily absorb it. In this Investigation, sodium hydroxide (NaOH) pellets react with the carbon dioxide as it is produced:

$$2NaOH + CO_2 \rightleftharpoons Na_2CO_3 + H_2O$$

Other chemicals that could be used are potassium hydroxide, calcium hydroxide, calcium oxide, and magnesium oxide.

Activity time: 40 minutes

Materials (groups of 4):

seeds (1 packet each of radish, corn, green bean, and garden peas)
7–14 test animals (more if very small) Mealworms and sow bugs are easy to obtain and keep.
150 NaOH pellets
string
14 pieces of filter paper, approximately 2 cm × 8 cm
8 test tubes (16 × 150 mm) with one-hole rubber stoppers (#1)
8 35-cm pieces of thick-walled capillary tubing
food coloring or washable ink
8 pieces of graph paper
transparent tape
petroleum jelly or liquid soap
clock or 7 watches with second hands

Any small plant or animal will work. The smaller the organism, however, the slower the bubble will move through the L-tube. The animals should not be dexterous enough to climb onto the package of pellets. Any small organisms obtained and used now can be saved for later Investigations.

Small plants like mosses are also useful. Encourage the use of seeds because this will broaden the base for generalizations on gas exchange. A respirometer with about 2 cm of seeds that have been soaked for 24 hours will generally produce readable results. A little cotton under the seeds will absorb excess moisture.

Preparation

Place the seeds between layers of wet paper towels for 24 hours before use, to start them sprouting.

Prepare the absorber packets by folding the filter paper pieces in half and stapling the edges. Place 10–15 NaOH pellets in each packet. As you staple the last open end, place a short piece (5 cm) of string under the stapler. Make two bags per group. Store in an air-tight container.

Make the 8 pieces of thick-walled capillary tubing into L-tubes by bending the glass 5 cm from one end. Hold both ends of the tube and heat the area you want to bend over a burner or propane torch. Rotate the glass between your fingers to evenly heat the glass. When the glass begins to sag, remove the tube from the flame. Quickly and smoothly bend the glass into a 90° angle. Fire polish both ends of each glass L-tube by holding the ends in a flame until the ends look smooth.

Insert the glass tubing into rubber stoppers before class to save time and lessen the chance of students cutting themselves. Lubricate the glass tubing with liquid soap or petroleum jelly before inserting into the stopper. Never push on the end of glass tubing with the palm of your hand. To avoid cutting yourself, grasp the tubing with a paper towel, exert gentle pressure, and rotate the tubing when pushing it through a stopper.

Add several drops of food coloring or washable ink to 10 ml water, so the liquid shows up well in capillary tubing.

A simple control for this experiment is a respirometer containing only the sodium hydroxide packet. The control can be observed (and data recorded) along with the one containing the organism. One empty setup would suffice for the whole class. Remember to wait five minutes before putting the drop of colored water on the end of the tube. If you do not wait, the bubble will move as the absorber removes the initial carbon dioxide present in the tube.

You could also use a piece of rubber tubing to attach a second respirometer to the open end of the L-tube. Changes in room temperature and atmospheric pressure should affect both tubes equally, causing no movement of the bubble. Any change in

the bubble would likely be due to one difference between the two jars—the organism.

Analyzing data

1. The rate depends on the organism used. The rate can range from about 1 cm/minute to about 15 cm/minute.
2. Larger animals and more active animals use oxygen faster.
3. Active organisms can use oxygen up to three times faster than animals at rest.
4. Seeds use oxygen to metabolize their stored food as they germinate. You could take the rate of oxygen used by all the seeds and divide it by the number of seeds in the sample to find out how fast one seed uses oxygen.
5. See previous discussion of possible controls.

7 Designing experiments

Behavioral Objectives

The students will learn

1. to design a controlled experiment.

They will show they have learned

1a. by designing an experiment to collect data to test a hypothesis. (Extend Your View 7-1)

1b. by using a checklist to evaluate the design of an experiment. (Extend Your View 7-2)

Overview

In this Investigation, the students create their own experimental designs. Students first become familiar with gill-cover beating and gas exchange in goldfish. They suggest at least one hypothesis to explain a described change in goldfish breathing behavior, and then design and conduct an experiment to test the hypothesis. They may make graphs of their experimental data to help interpret it.

Background

The movement of the gill covers allows the goldfish to respire. The rate of movement is one index of its rate of gas exchange and its metabolic activity.

The rate of gill-cover beat depends on the fish itself and external factors. The age, size, activity of the thyroid, and the amount of movement of the fish affect its rate of respiration. The temperature and oxygen concentration of the water are two of the most important external factors that modify the beating of the gill covers.

Investigation 7-1 The goldfish puzzle

You may want to use the photographs on pages 88 and 89 to introduce this Investigation or to help summarize it. These photographs will not only give the students more practice in making hypotheses but will show the practical application of this process. The photographs are of Leonardo da Vinci's sketch for a flying apparatus, one of the Wright Brothers' planes, a car of the future, and a modern housing complex called Habitat.

Students may work alone or in groups to develop hypotheses about the goldfish. Then students with compatible hypotheses can work together in groups of three or four to design their experiment. If the students need help designing experiments, you could discuss a related experiment that pertains to goldfish breathing rate. For example, you might discuss the effects of aeration or aquatic plants on the fish's breathing rate.

Permit students to carry out designs even if the designs have flaws, such as a lack of controls. The flaws can be identified later when the data is interpreted. If there is enough student interest, you might allow them to do their experiments over again or test new hypotheses.

The hypothesis that the breathing rate was reduced by a decrease in water temperature during the night can be tested by *gently* adding ice cubes, one at a time, to lower the water temperature. When the temperature reaches predetermined points, the gill-cover beats and water temperature should be recorded. Someone may suggest placing the fish in a refrigerator. This design also excludes light, and provides a good opportunity during analysis of data to discuss the need for controls.

The hypothesis that light intensity affects the breathing rate can be tested by reducing the light

intensity while keeping the temperature constant. One method is to cover one fish container, except for an observation window, and expose another to light. A more sophisticated experiment uses a series of light bulbs of increasing wattage. The fish should be exposed to each level of light intensity for a few minutes before the beat rate is counted. Several counts, spaced by equal time intervals, should be made for each level of intensity.

It may be difficult to keep the water temperature from rising. The students could measure the water temperature and try to control it with small amounts of ice and hot water. Or they could simply check the temperature and record it as an uncontrolled variable. Do not discourage the testing of *if-variables* other than light and temperature.

Before experiments are started, take time to explain safety procedures for both students and goldfish. Spilled water is a hazard and should be wiped up. Make sure the experimental designs, especially in temperature-testing, do not change conditions drastically. Outright mistreatment could injure or kill the fish.

Also discuss the *Checklist for designing an experiment.* The *Checklist* should be used in this Investigation and referred to in future Investigations to help students evaluate experimental designs. Discuss *Checklist* questions they do not understand or other questions they feel should be added to the list.

Activity time: 2 class periods This includes time to plan and conduct the experiment. More time may be needed for analyzing data.

Materials (groups of 4):
16 goldfish, at least 7.5 cm long
16 quart or litre jars
several lamps (incandescent and/or fluorescent)
ice cubes
8 thermometers
clock or 8 watches with a second hand

The design of a specific experiment may require additional materials.

Preparation
Several groups of students can use the same fish during a day. The water should be allowed to return slowly to room temperature and remain there for at least one hour before the fish is exposed to new temperature changes. If a fish is used alternately as the control and the experimental organism, it will be exposed to fewer significant temperature changes. Label each fish's container.

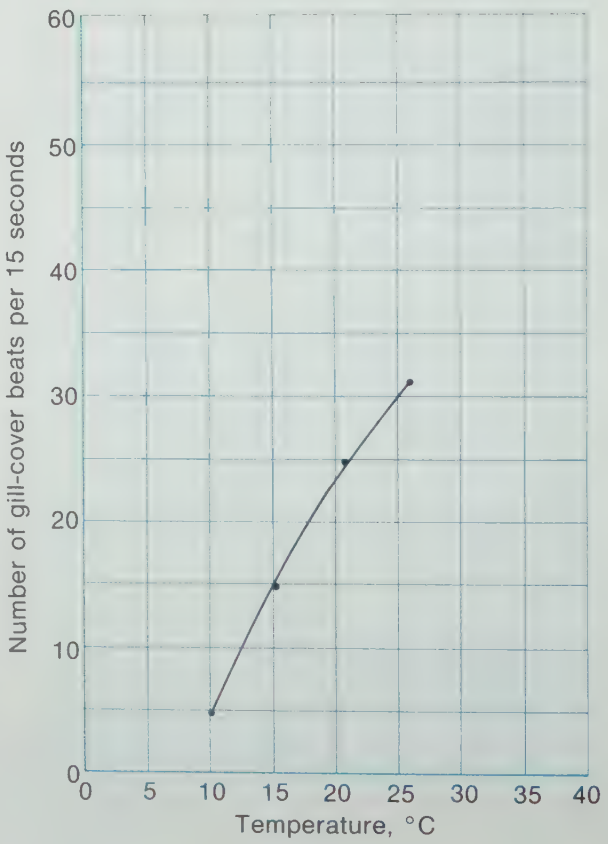
Tap water should be dechlorinated by letting it stand in an open container for at least 24 hours at room temperature. Ice should be made from dechlorinated tap water. One bag of cubes is enough for several classes.

Analyzing data
1. Some groups may decide to graph their results. It is important to gather enough data to show a relationship, if one exists, between the variables being measured. At least four points should be plotted for each graph. If a pattern is revealed, a line or curve can be drawn to fit the data points. A random scattering of points would indicate no apparent relation between the two variables.

   Generally, graphs of temperature and gill-cover beat rate show a direct relationship, while graphs of light and gill-cover beat rate show none. (If light and gill-cover beat rate seem to show a relation, it may be due to the light's warming effect on the water.)

   Figure 7-1T is an example of a graph that could be made for this Investigation. The *if-variable,* temperature, is plotted on the horizontal axis, and the *then-variable,* gill-cover beats, is plotted on the vertical axis. Some students may want to make bar

Figure 7-1T



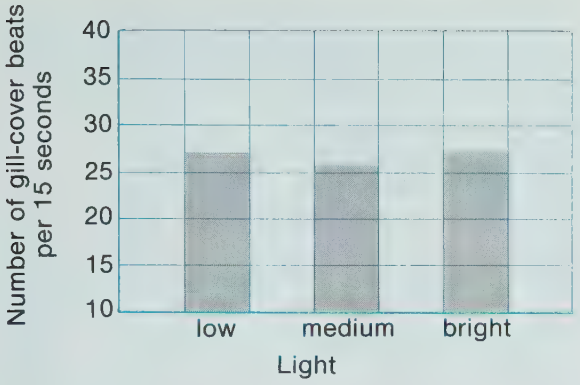


Figure 7-2T

graphs, like Figure 7-2T for gill-cover beats versus light. Some may want to graph results that are not entirely quantitative. Let them try and they will discover the need for quantitative data.

2. Students should understand that an experiment that does *not* support a hypothesis may be just as successful as one that does. The experiment has served the purpose of eliminating one variable as the cause of a change in behavior.

References

Atz, James W. "The Supersensitivity of Fishes." *Natural History,* November 1972. Discusses the extreme sensitivity of fish to small changes in their environment.

8 Learning

Behavioral Objectives

The students will learn

1. that learning can be measured in terms of a specific task or problem.
2. that learning can be studied experimentally.
3. that learning can be inferred from a graph.

They will show they have learned

1. by identifying changes in behavior that could be used to measure learning. (Extend Your View 8-1)
2. by designing an experiment to measure changes in behavior. (Extend Your View 8-2)
3. by interpreting a learning-graph. (Extend Your View 8-3)

Overview

In these Investigations, the students study learning experimentally. Investigation 8-1 explores maze-learning by humans. Investigation 8-2 provides a simulation for studying maze-learning by rodents. Students will examine the performance of laboratory animals in a maze by using a set of data-generating cards, contained in *The Mouse in the Maze.* In Investigation 8-3, an optional Investigation, students study how a rodent learns to escape from a confined place.

Background

To learn is to change behavior as a result of experience. Most animals are capable of simple kinds of learning. For example, the planaria, a flatworm, is able to negotiate a simple, one-T maze. Animals with central nervous systems display increasingly complex kinds of learning. Primates learn simple habits like shaking their head to mean "yes" or "no." They can also learn complex skills like language.

Learning is generally studied by first defining the task or problem given to the potential learner. The learner's performance is then measured as objectively as possible, preferably in quantitative terms. The kinds of learning that take place over long periods of time, often involving subtle changes in behavior or beliefs, are not easily studied in learning experiments (or picked up in tests, or specified in behavioral objectives).

Data from learning experiments is usually analyzed in the form of a learning-graph. Figure 8-1T shows two highly idealized learning-graphs. Learning seldom takes place so smoothly. The two different measures of performance used in these graphs give graphs of similar shape.

The patterns in these graphs might have been predicted by common sense alone. The slope of each curve is greatest at the beginning when there is more to learn. Each curve reaches a plateau that indicates the limit of the organism's performance under the given conditions.

Not everyone learns all tasks equally well. Unfortunately, an individual's performance (or nonperform-

ance) in one learning task is sometimes extended by the observer to all learning tasks. Those students called "under-achievers" have often made this same mistaken generalization about themselves. Learning and rates of learning should be described only in relation to the specific task at hand.

The concepts of "smartness" and "intelligence" may come up in class discussion. Although intelligence is often defined as the ability to learn, play down ideas about general intelligence. The activities in this Investigation deal with limited kinds of learning, and students should not infer overall intelligence from such an inadequate base. I.Q. simply reflects the ability to perform one limited task—answering the questions in I.Q. tests. All conclusions about total intelligence based on I.Q. scores are inferences.

Investigation 8-1
Maze-learning

You could introduce the Investigation by posing questions about learning by various animals. Can they or can they not learn? Can some animals learn more or faster than others? Does the ability to learn change with age? Refer to specific animals such as household pets, porpoises, and humans.

In this Investigation, students learn that reliable data depends on repeated experiments using the same procedure each time. Emphasize experimental design, control of variables, and graphic analysis. Be sure to keep the discussions focused on the processes of learning, or students may mistakenly view the experiments as tests.

Activity time: 40 minutes

Materials (groups of 2):

14 T-mazes, either pencil (preferred) or finger type
clock or 14 watches with second hands
14 blindfolds, a paper towel, or a strip of cloth held in place by a rubber band
28 sheets of graph paper

Preparation

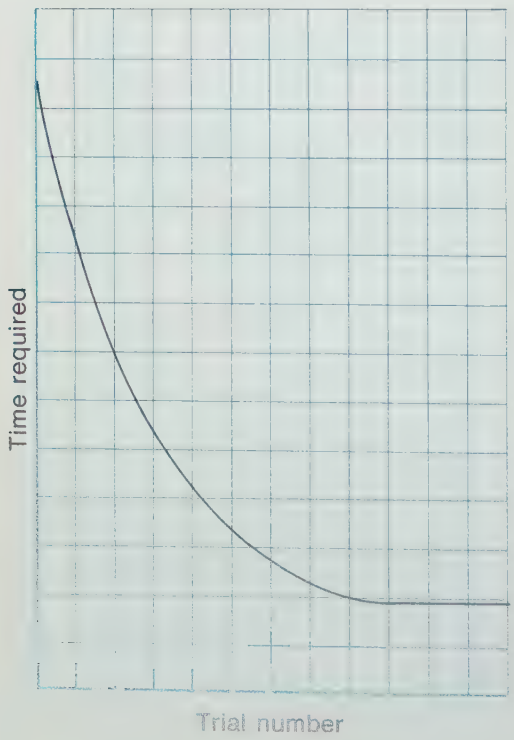
To make a pencil maze (See Figure 8-2T.).

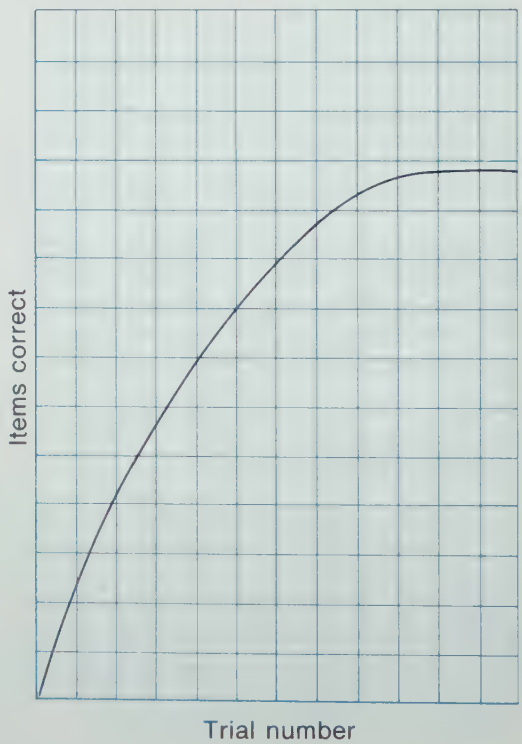
1. Trace on a manila folder or heavy construction paper either Figure 8-3T or 8-4T (pages T44–T45).
2. Use a single-edged razor blade to cut along the traced outline and remove a channel.
3. Fasten a paper backing to the manila folder with glue or rubber cement.

To make a finger or ridge maze:

1. Trace on typing paper the dotted pattern in Figure 8-3T or 8-4T.
2. Put a piece of soft cardboard under the paper. Using a large pin, such as those on political badges or slogan buttons, make holes along the dotted line. Holes should be no more than 2 mm apart.

Figure 8-1T





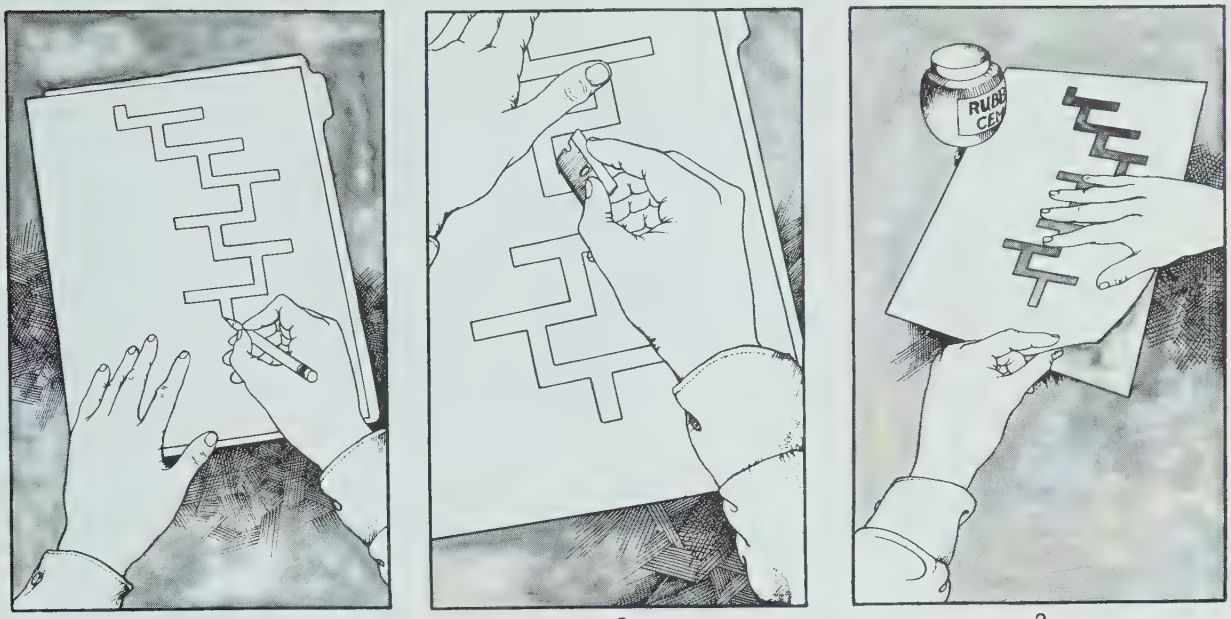


Figure 8-2T 1 2 3

3. To use the maze, turn the paper over. The holes are now a series of raised points that students can follow with their fingertips.

Analyzing data

The students were testing the hypothesis that time decreases as the number of trials increases. Number of trials is the *if-variable;* time to run the maze is the *then-variable.*

Students may ask what kind of graph to make. A line graph could be made, but remember that the *if-variable* (trials) is not continuous. There can be no trial between Trial 1 and Trial 2. A bar graph could also be made.

1. Learning is shown by an improvement in performance—difference in time between early trials and later trials. The most learning has occurred when the difference between the starting and final performance is greatest.
2. The subject used memory to learn the maze.
3. By the 10th trial, most students will be approaching their limit of performance on this task. The time for the 20th trial will probably be only slightly faster than for the 10th.
4. Slower learning gives a more gradual curve (a smaller slope). The steeper the curve, the faster the learning.
5. With the same maze and subject, the time for the first trial on the second day would probably be shorter than for the first trial on the first day, but longer than for the last trial of the first day. There would be some loss of learning, but the subject would probably not return to the initial stage.

With a different maze, the students might get a graph similar to the one from the first day. The graph might be steeper, if they learned any skills that could be applied to mazes in general.

Investigation 8-2
The Mouse in the Maze

A simulated experiment has the same purpose as any other experiment—to obtain data for answering a question or testing a hypothesis. Instead of manipulating equipment and laboratory animals, the students manipulate a set of perforated cards. The data they obtain from the simulated experiment *is* realistic. It is subject to experimental error, just like data from a real experiment, and it can be graphed by students.

The data cards and the perforated cards, which determine experimental conditions in *The Mouse in the Maze,* are computer-designed. The computer program is based on summaries of many actual maze-learning experiments using rodents.

Activity time: 40 minutes Extra time may be needed if students want to test a number of hypotheses.

Materials:

The Mouse in the Maze, available from Houghton Mifflin Company. Contact your local sales representative or regional office.

56 sheets of graph paper

Ideally, each pair of students would have one set of cards. But this may not be practical. Some students could do the Investigation during study periods, after

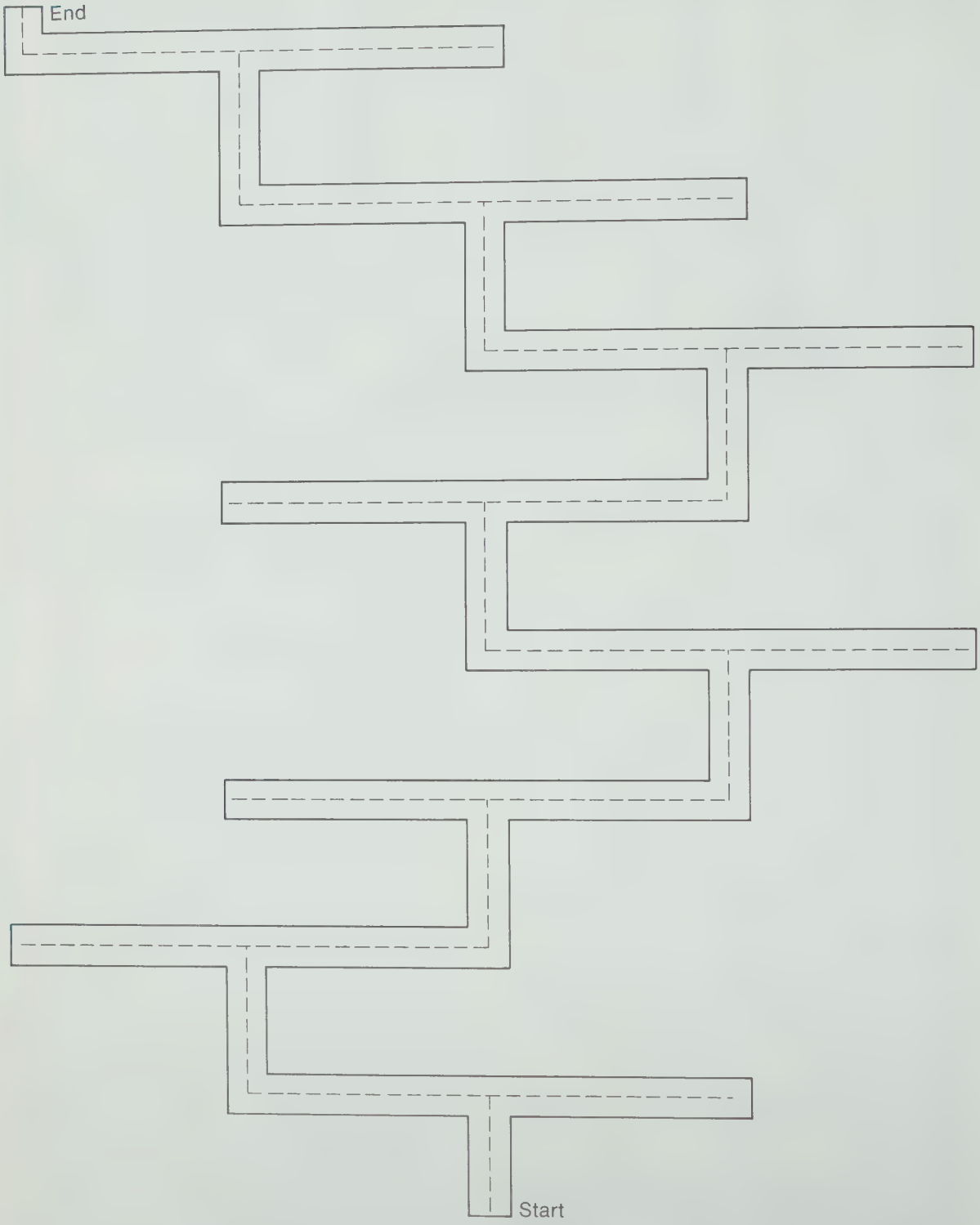


Figure 8-3T

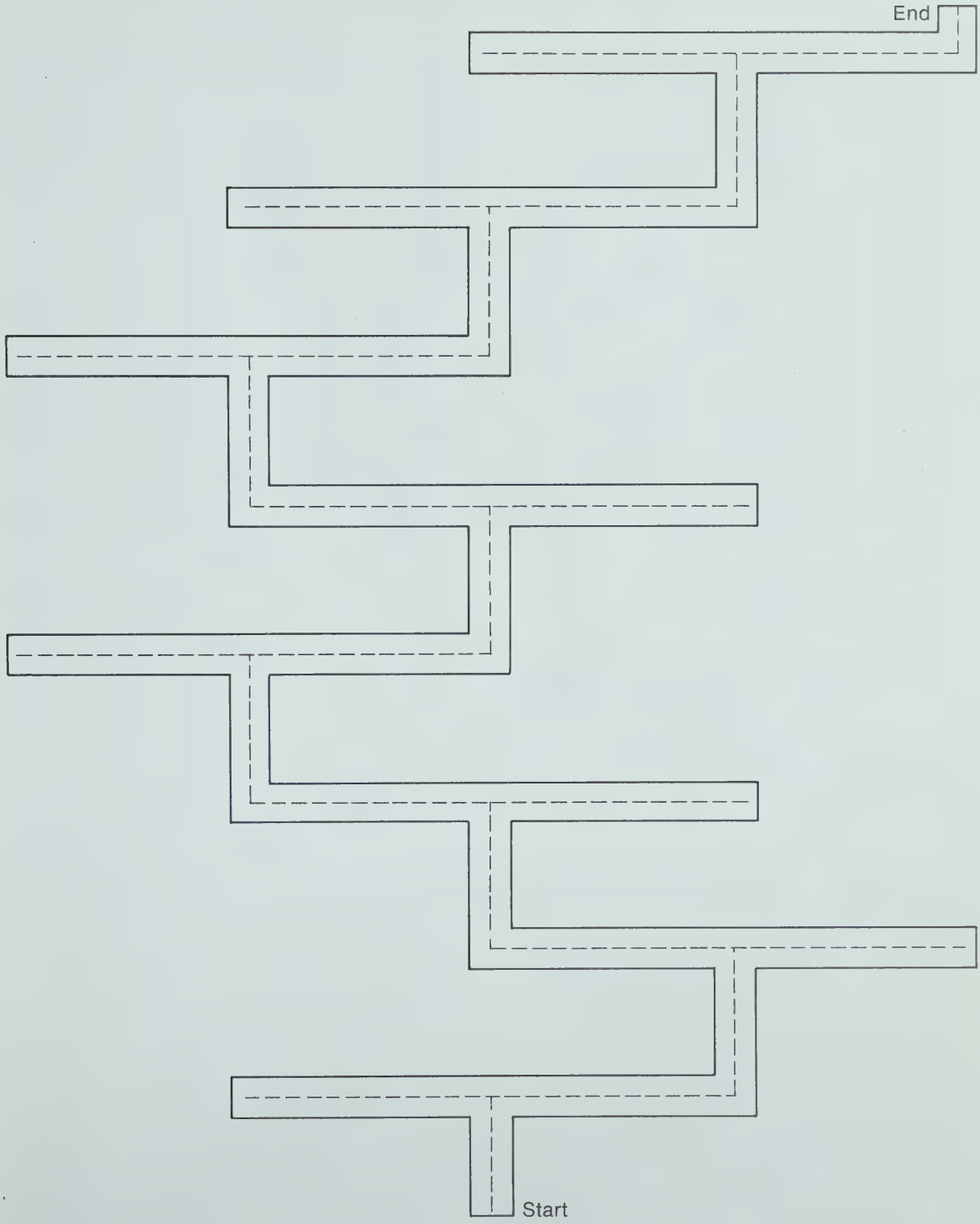


Figure 8-4T

school, or at home. Some students could do this Investigation while others are doing Investigation 8-1.

Analyzing data

1. All the animals learned. They all had faster times or fewer mistakes on later trials.
2. All the rodents learn rapidly initially. The learning-graphs begin to level off between Trials 10 and 15.
3. Both humans and rodents learn most at the beginning. Both seem to have a limit to their performance. Since memory plays a part in maze-learning, humans probably have an advantage.

Prediction is a useful tool for analyzing data for two reasons. In order to predict, one must first decide whether or not there is a pattern to the experimental data. Secondly, if there *is* a pattern, one must decide over what range the pattern holds.

To estimate the value of a factor outside the range of given data (to extrapolate), one extends the plotted line or curve. To estimate values within the range of plotted data (to interpolate), one simply reads values off the line already drawn. That line already predicts what values the experimental factors would have if further measurements were made.

Investigation 8-3
Can animals learn to escape?

This Investigation is optional. Students might also try alternative experiments with real animals. For example, can mice learn to discriminate between shapes and between light and dark figures? You should be aware, however, that mice vary greatly in learning ability and can also become "bored." Gathering reliable data may be difficult.

Activity time: 40 minutes

Materials (class):

one naive, hungry animal such as a mouse, hamster, or gerbil
one well-fed animal (same species as the hungry subject)
one unglazed, clay flowerpot (not plastic, which is slippery). The depth of the pot should be equal to the total length of the animal, including its tail.

Preparation

One animal must be hungry. Do not feed it for 24–48 hours (but no longer than 48) before the experiments. The animals used in each class should not have been used previously in a similar situation. Otherwise, they may have already learned the skill.

Analyzing data

1. If food is provided, a hungry animal will probably learn to escape. A well-fed animal's performance is not as easy to predict.
2. This will be a direct observation by the students.
3. The subject, the task, the container, and the presence or absence of food are all variables. So are conditions such as light, noise, and temperature.
4. The general shape of the learning-graphs should resemble those obtained in Investigation 8-2.
5. Frogs, insects, household pets, or humans could be tested. Equipment would vary with the size and capabilities of the organism.

Additional questions for discussion: What results would you predict if the same series of experiments were done tomorrow, using the same animals? How might different kinds of food affect the experiment?

References

Chauvin, Remy. *The World of Ants.* New York: Hill and Wang, 1969. The section beginning on page 179, "Can ants learn?", discusses the role of the exploratory urge in the learning behavior of ants.

9 What is a suitable environment?

Behavioral Objectives

The students will learn

1. that an organism responds to changes in its environment.
2. that an organism's responses to its environment have survival value.

They will show they have learned

1. by hypothesizing what kind of environment would best match an organism's needs. (Extend Your View 9-1)
2. by inferring how an organism's response to its environment helps it to survive. (Extend Your View 9-2)

Overview

Students now use their basic skills in making hypotheses and designing experiments in a more complex situation. In Investigation 9-1, the students collect a small organism, gather data about its natural environment, and try to design a home for the organism. In Investigation 9-2, the students make hypotheses about their organism's response to variations in one environmental condition. The students design and do experiments to test their hypotheses.

Background

The ability of an animal to keep itself alive and reproduce depends on its interaction with both its physical environment and other organisms. The more adaptive an animal's behavior, the more likely it is to survive.

Survival may involve the dramatic struggles of predators and prey. But survival is just as likely to depend on an animal's daily success in finding a suitable physical environment and adapting to changes in this environment. A large part of an animal's behavior is directed toward these goals.

Much information has been gathered, mostly during the last 50 years, about "orientation behavior" in animals. Orientation behavior includes the reactions that guide animals to their normal habitats, for example, salmon returning to freshwater to spawn. Another type of orientation behavior is the signals that bring male and female animals together for reproduction.

These Investigations focus on animal orientation related to environmental variables such as light, temperature, heat, odors, and the color and texture of the surroundings. Since animals react to more than one variable at a time, well-controlled experiments are necessary to determine the effect of a single variable on behavior.

To say that an organism "chooses" moist conditions to avoid death from dessication is to imply that the organism has some purpose in mind. There is no evidence that most animals learn this from experience, communicate with each other, or have insight into the situation. Genetics provides one logical answer. Those organisms that do not inherit the "preference" for moist places do not survive long enough to produce offspring. Their nonadaptive behavior is not passed on to the next generation.

The term "environment" is used to mean the surroundings that have an influence on the organism. Later Investigations will help students expand their concept of environment and the factors that influence organisms. A summary discussion of the topic at the end of the program would be useful.

Investigation 9-1
Making a home for an animal

There are several options for selecting organisms.

1. Let the students choose any small organisms, but be sure they check with you before bringing them in. If you are familiar with the necessary care for a number of organisms, this should be no problem.
2. Let students select from two or three organisms that you suggest. These might include beetles, earthworms, or sow bugs.
3. Purchase from a pet store or supply house mealworms, snails, or crickets for use by the class.
4. Have the class investigate only one organism. In Investigation 9-2, you could encourage each group to investigate the effects of a different variable, and the class would have a wealth of data on the behavior of one organism.

Some organisms should be avoided. Small turtles (from pet stores) can carry the dangerous *Salmonella* bacteria. Bees, wasps, hornets, and some ants sting. Most spiders carry venom, although in temperate North America only the black widow and recluse spiders are known to be harmful to humans.

Spend time in class discussing the humane treatment of living things. Ask the students to consider how

they would feel if they were the subjects of a similar experiment.

Activity time: 2–3 class periods
Introducing the Investigation: 20–40 minutes
Observation and research: 40 minutes
Construction of home: 40 minutes

Materials (groups of 4):
plastic shoe boxes, milk cartons, or other containers that could be fashioned into homes
1 box of oatmeal or bran
peat moss
6 large sponges These can be cut into smaller pieces and dampened to provide moisture in the homes.
reference books

Analyzing data
Refer to the Background for a list of likely variables. Each item included in the home should be related to one or more of the variables on the list.

Investigation 9-2
How does your animal respond to different conditions?

This Investigation is usually more successful if students work in groups of three or more, since they are more likely to generate good ideas working together. Give students freedom to experiment. The hypotheses that they choose should be limited only by their imaginations (and possibly the lack of specific equipment). This will impose an additional responsibility on you as a provider and organizer of materials and as a consultant. At the conclusion of the activity, you will need to help students synthesize the results of a number of diverse investigations.

The more specific the hypothesis, the easier it will be to test. Have the students predict which location the organism will move toward or the relative periods of time it will spend in each of a number of locations.

Students can assemble their own "choice chambers" and other equipment or use those already made in other classes. They may need help choosing materials to test their hypotheses. In most cases more time will be required to set up experiments than to obtain data. For example, data for testing the hypothesis that sow bugs prefer dark to light can be obtained in less than 15 minutes.

By now most students should be able to design controlled experiments. However, some students will probably need help in designing effective ones. Identify the variables the students plan to investigate. A student may choose a variable that is impossible to control. For example, an animal's movement into the soil of its container might actually be a response to light, humidity, odors, temperature, or any combination of these factors.

Activity time: 2 class periods
Assembling equipment: 40 minutes
Testing hypotheses: 40 minutes

Materials (groups of 3):
Petri dishes, drinking glasses, or medicine bottles (all plastic)
2–3 metres of glass or clear plastic tubing, a bore of at least 6 mm
several triangular files
several tubes of plastic cement
test tubes, 16 × 150 mm
several cotton balls
thermometers, at least 4 for each temperature-gradient chamber

These items may also be useful:
flashlights (students can bring these from home)
several small artist's paint brushes
paints, 4 or 5 bright colors
up to a square metre of ¼-inch plywood or styrofoam sheets
several sheets of fine, medium, and coarse sandpaper
Humidity Indicator Cards, range 10–100 percent available from:

Humidial Company
P.O. Box 464
465 Mount Vernon Street
Colton, California 92324

These may also be used for Investigation 12-2.

50 ml 5% cobalt chloride solution (if Humidity Indicator Cards are not used)
6 8-watt bulbs, 1 for each temperature-gradient chamber
pin socket for each light bulb
25 square metres of clear plastic wrap
white filter paper, at least 10 cm in diameter
anhydrous calcium chloride
ice cubes
masking or transparent tape
colored cellophane
black plastic sheeting
whole white potatoes
vinegar
vegetable matter, several kinds in the process of decaying, (for example, lettuce leaves discarded by the supermarket)
granulated sugar
salt
onions

Preparation

Temperature- and humidity-gradient chambers can be made from wood or styrofoam.

Indicator paper for humidity chambers can be made by dissolving 2.5 g of cobalt chloride in 47.5 ml of water. Soak white filter paper in this solution, and dry. Store the dry paper in a tightly-closed glass jar.

You may want to have mealworms on hand for those who do not collect other organisms. Mealworms are available at local pet stores and biological supply companies. Culture the mealworms in jars half-filled with oatmeal or dry bran. Lay a small piece of moist sponge on the surface of the medium. If mold appears, remove the moldy portion.

Analyzing data

Have students discuss their inferences about the survival value of their animal's behavior in its natural environment. These generalizations about animal behavior will probably emerge from the class discussion:

1. Much of an animal's behavior is directly influenced by its environment.
2. When conditions change, there is usually a corresponding change in the organism's behavior.
3. Many of the responses of organisms help them adapt to their environment.
4. Most organisms will not be found evenly distributed over a given area but will be limited to scattered areas where conditions are most suitable for survival.

References

Kramer, David C., "Isopodo: the Un-Bugs." *Science and Children.* January and February 1974. Methods for keeping sow bugs in the classroom.

Masteller, E. C., "Live Insects in the Classroom and Laboratory." *The American Biology Teacher,* October 1970. Techniques for maintaining insects.

Stong, C. L., "The Amateur Scientist: How to study learning in the sow bug." *Scientific American,* May 1967. How to set up a home and a training-maze.

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Chicago, Illinois 60620

No. 7 The Care of Frogs and Other Amphibians
No. 28 Reptiles in the School Laboratory
No. 34 The Care of Living Insects in the School Laboratory
No. 35 Studying Ants in Observation Nests
No. 41 Collection and Culture of Earthworms and other Annelids

10 How does light affect euglenas?

Behavioral Objectives

The students will learn

1. that some organisms respond to changes in color and intensity of light.
2. that the light-sensitive behavior of photosynthetic organisms helps them to survive.

They will show they have learned

1. by predicting the response of euglenas to variations in the intensity and color of light. (Extend Your View 10-1)
2. by inferring how different responses to light help organisms to survive. (Extend Your View 10-2)

Overview

Students will become familiar with euglenas by observing the euglenas through a microscope. In Investigation 10-1, the students do a simple experiment to determine how euglenas respond to light and dark. Then in Investigation 10-2, they design and do an experiment to show how euglenas respond to variations in light intensity or color.

Background

In Investigation 6-1, students learned that both plants and animals respire. Photosynthetic organisms carry on photosynthesis in addition to respiration. In the light they respire, but at a slower rate than they photosynthesize. Photosynthesis is a complex process. The first steps (photolysis) are light-dependent. Later steps (CO_2-fixation) can take place in the dark. But since

these later steps use products of earlier steps, the total process is dependent on light.

During photosynthesis a plant uses carbon dioxide and water, in the presence of chlorophyll and light, to make carbohydrates and oxygen. The many reactions that make up this process can be summarized as follows:

$$CO_2 + H_2O \xrightarrow[\text{light}]{\text{chlorophyll}} (CH_2O) + O_2$$

(CH_2O) stands for one unit in a carbohydrate chain. For example, the carbohydrate glucose, a simple sugar, has the formula $(CH_2O)_6$ or $C_6H_{12}O_6$.

In the first steps of photosynthesis, sunlight is absorbed by chlorophyll and changed into chemical energy. The chemical energy is used to convert water and carbon dioxide into carbohydrates; first into sugar, and then, if the sugars are not metabolized, into starch. Oxygen is a product of this process. In this way energy from the sun is stored in the chemical bonds of the carbohydrate molecules.

A euglena is a one-celled organism that grows to 0.1 mm in length. It was chosen as the experimental subject for this Investigation because it is easy to culture and maintain. Euglenas possess chlorophyll and carry on photosynthesis in the presence of light. For complete nutrition they require traces of dissolved organic materials. But, like animals, they can move to more favorable conditions. If they are subjected to prolonged darkness, the chlorophyll disappears. Colorless euglenas can live and reproduce for a time, if supplied with a rich nutrient solution.

Near the base of the whiplike flagellum, which propels a euglena through the water, is a dense body that is sensitive to light. This reddish-orange body is called an "eye-spot." The "eye-spot" enables the euglena to locate itself in an area where the light is favorable for photosynthesis.

Investigation 10-1
How do euglenas respond to light and dark?

Organisms like euglenas appear to move very rapidly when observed under a microscope. To slow down their movement, two techniques are useful. Adding a few cotton fibers provides barriers and restricts movement. Enough fibers should be used so that an enclosed area containing a few euglenas can be seen. In this way the euglenas will remain in the field of vision.

Another method is to use a toothpick dipped in methyl cellulose to make a small ring on a clean slide. Then a drop of *Euglena* culture is put into the ring and the slide is covered with a cover slip. The viscous methyl cellulose will slow down the euglena.

Activity time: 1–2 class periods
Working with microscopes: 20–30 minutes
Setting up experiments: 15–20 minutes
Making observations on the second day: 10 minutes

Materials (groups of 2):
handful of dried split peas or *Euglena* culture medium
14 25-ml vials (sometimes listed as 2 drams)
14 stoppers or cotton plugs for vials
2 ml methyl cellulose (or a few cotton balls)
toothpicks
1 litre *Euglena* culture, stored in a flask or bottle
microscopes (ideally 14, but at least 7) If microscopes are not available at your school, consider borrowing them from the high school.
28 slides
28 cover slips
14 medicine droppers
14 sheets of black construction paper
several hand-held paper punches
masking tape
7 scissors

Preparation
One litre of fresh, actively-growing, and densely-populated *Euglena* culture is sufficient for three classes of 28 students. The small amount of *Euglena* needed to start the culture can be purchased from a biological supply company.

There are two easy methods for preparing the actively-growing culture.

1. To a litre of spring water or tap water left standing for 24 hours, add 40 wheat grains, 35 rice grains, and 5 g dry skim milk. Boil for 5 minutes. Let the solution stand overnight before adding the euglenas. The stock culture can be kept in a litre flask plugged with cotton or covered with gauze. The plug should be dense enough to prevent mold and bacterial contamination.
2. Add 40 split pea halves to a litre of water and boil for 10 minutes. When the solution has cooled, discard the solid residue and add the euglenas.

Keep the culture in constant illumination, but not direct sunlight, to enhance the rate of reproduction. The culture should be ready to use after about two weeks or whenever the medium is heavily green and almost opaque. Divide it out into 25-ml glass or transparent plastic vials. Screw the caps on or set the cotton plugs loosely. The loose covers minimize the chance of bacterial or mold contamination while still allowing for gas exchange in and out of the containers.

Be sure to keep the vials of euglenas or the stock culture in the dark for 24 hours before they are used. This makes the euglenas respond more strikingly and rapidly to light.

To prepare the methyl cellulose solution, add 10 g of methyl cellulose to 90 ml of water. Mix as well as you can and leave for 24 hours. The methyl cellulose solution can also be purchased from a biological supply company.

Analyzing data

Since results may vary, students should compare results. Euglenas will avoid bright light. Whether or not euglenas gather near the hole in the black paper will depend upon the intensity of the light used and the distance from the light to the sample.

The results should provide a number of questions about light intensity that can be tested in Investigation 10-2. Refer to the Background for a short discussion on the survival aspects of euglenas' response to light.

Students must understand that the green material in the euglenas is chlorophyll. They must also know that chlorophyll gives an organism a way to convert light into food energy. Then the reactions of euglenas to light will make sense.

Investigation 10-2
What kind of light do euglenas prefer?

The effects of different colors of light on euglenas' behavior can be investigated by masking their containers with dark paper and colored cellophane. Each mask should exclude all light except the light coming through the window of colored cellophane (Figure 10-1T). The masks should be cut and taped so that they can be removed without stirring up the culture in the container.

You might suggest that the students repeat the experiment. The second time they would reverse the mask so that the blue filter is near the top of the vial and the red near the bottom.

The effect of varying light intensity on euglena behavior can be investigated with similar equipment. Use filters of waxed paper or frosty transparent tape to replace the colored filters. The thickness of the intensity filters varies between 5 and 14 layers of waxed paper (Figure 10-2T). Neutral density filters will do the same job and can be purchased from camera stores.

A design like this will produce a wide range of responses. The light falling on the surface should not be too intense or the filter will not discriminate. Bright daylight from a window about five metres away will work well at the filter thicknesses recommended.

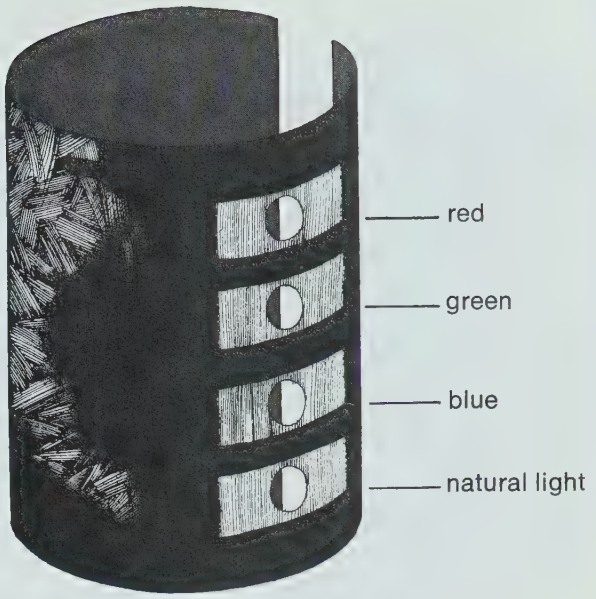


Figure 10-1T

Optional demonstration

The range of wavelengths in white light can be separated into a spectrum with a prism or diffraction grating. You can project the spectrum on a screen or wall.

Diffraction gratings can be purchased in sheets (30 cm × 30 cm) or on slides (5 cm × 5 cm). Make a slide out of black construction paper and cut a slit 1 mm × 16 mm in the middle. Mount the diffraction grating in a cardboard frame and tape it to the end of the lens barrel of the projector as shown in Figure 10-3T. The lines in the grating should be parallel to the slit in the black paper. The projector should be no farther than one metre from the screen or wall. The spectrum will appear to the left and right of the bar of white light cast on the screen. You can also use a prism as shown in Figure 10-4T.

Activity time: 1–2 class periods

Materials (groups of 2):

vials of *Euglena* culture from Investigation 10-1
waxed paper or frosty transparent tape
black construction paper from Investigation 10-1
1 roll of red, blue, green, and yellow cellophane or colored, plastic filters
several hand-held paper punches
masking tape
scissors

Analyzing data

The euglenas will move toward an optimal light intensity that is somewhere between direct (and dangerous)

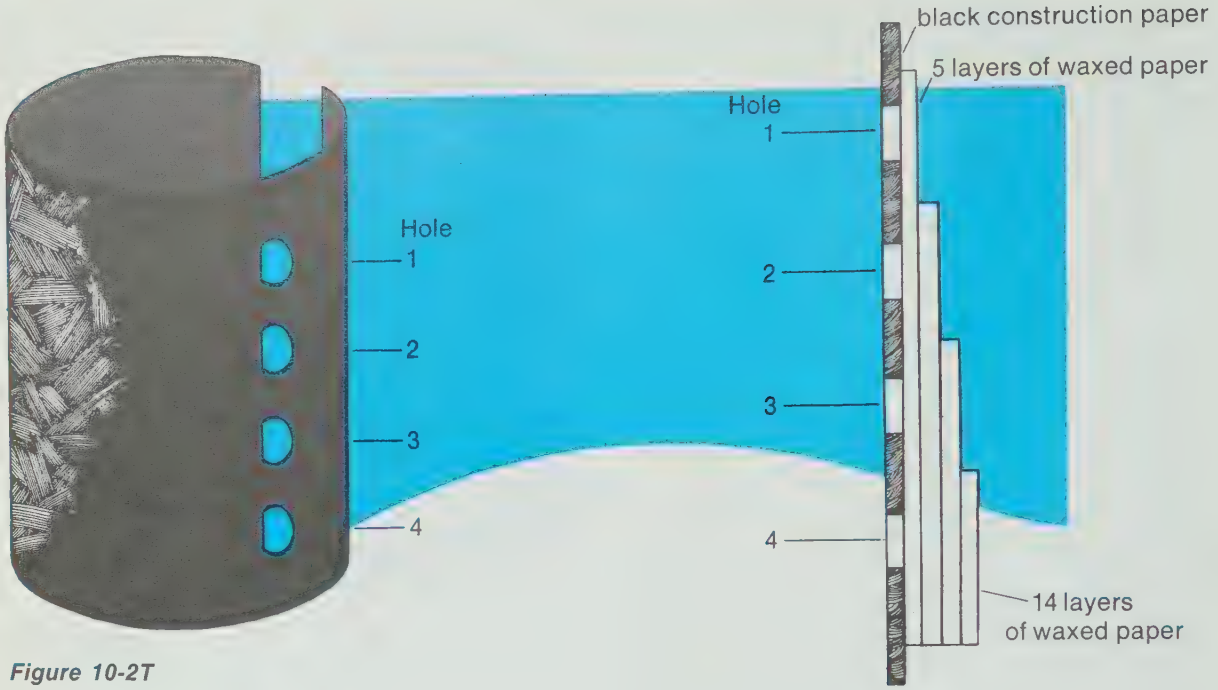


Figure 10-2T

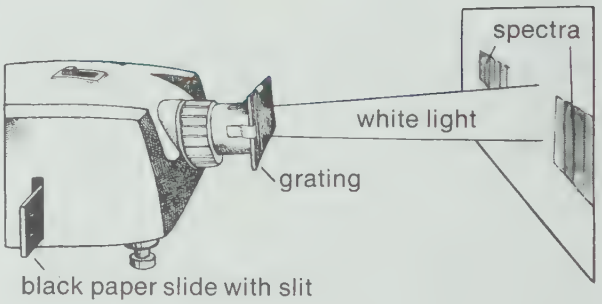
sunlight and darkness, where they cannot photosynthesize. If direct sunlight is absorbed by euglenas, it is converted to heat, and the euglenas "cook." Other photosynthetic organisms respond in a similar way. Most plants orient their leaves so their surface is exposed to the sun.

When light-hungry euglenas congregate in front of a filter, they produce shade for the others. You can therefore expect to find many euglenas tightly packed behind a favorable light filter (possibly even stuck to the glass) while many more in the container are randomly distributed in shaded light. Given a "choice" of filtered light of equal intensity, euglenas will generally congregate most rapidly and thickly at blue light, then red, yellow, and finally green.

References

Barthelemy, Richard E., Dawson, James R. Jr., and Lee, Addison E. *Innovation in Equipment and Techniques for the Biology Teaching Laboratory,* Boston: D. C. Heath and Company, 1964. (Paperback). Information on various filter materials such as plexiglass, plastic film, food coloring, and theatrical gelatin.

Figure 10-3T



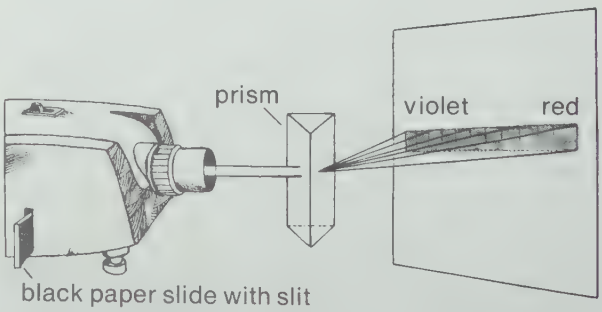


Figure 10-4T

11 What influences seed germination?

Behavioral Objectives

The students will learn

1. how variables such as water, temperature, and light affect the germination of seeds.

They will show they have learned

1. by using experimental data to identify what conditions affect the germination of different seeds. (Extend Your View 11-1)

Overview

These Investigations introduce the concept of behavioral responses by seeds and young plants to environmental factors. The class will read and discuss the introduction on seed dormancy and longevity. Then groups of students will investigate the effects of water, temperature, and light on various seeds.

The simplest way to proceed is for each group of students to work with one of the three activities. This procedure requires less material and time, but it also yields less data. By pooling the data from their germination experiments, students should be able to infer the survival value of various responses of seeds to environmental conditions.

After the first day (ideally, a Monday), observations will take only ten minutes per day. In the remaining time, students may do additional experiments. Or they may collect different kinds of seeds, and discuss their special adaptive features.

The group doing Investigation 11-1 makes observations for seven days on the effects of different seed treatments on germination. During this time, they do an additional three-day experiment on the effects of water on the appearance of seeds. The group doing Investigation 11-2 prepares seeds for germination at three different temperatures, and observes the effects for seven days. The group doing Investigation 11-3 prepares seeds for germination in total darkness and total light, and observes the effects after seven days.

Background

A dormant seed carries an embryonic plant whose life activities are at a minimum. There is no cell division or growth, and only a very low rate of respiration. The metabolic rate is reduced as the young seeds dry out after ripening. The seed is then in a state of dormancy and will remain dormant until conditions are favorable for it to germinate.

A seed can survive dry periods that might kill a young plant. Also, because of its low water content, the embryonic plant within the seed is not as vulnerable to extreme temperatures as a young plant. The seed's low metabolic rate enables it to survive on its stored nutrients for a long time.

Dormancy may continue for two reasons. The first, the focus of these Investigations, is that conditions are unfavorable for germination. Most seeds that still have the ability to germinate will do so as soon as there are favorable conditions. The seeds remain dormant if water, temperature, or light conditions are unfavorable. This is especially true of corn and other crops.

Dormancy may also result from chemical inhibitors that are present in the seed. Many flower and weed seeds possess this kind of dormancy. For example, some cactus seeds contain a chemical that inhibits germination until rain leaches it out. Tomato seeds cannot germinate in their own juices, which contain a germination inhibitor.

It is important to realize that water, light, temperature, and other factors that influence germination are interdependent, because together they make up the climate of a plant's natural habitat. Students may also choose to investigate the effects of other factors such as oxygen, carbon dioxide, and seed size. Procedures and apparatus for some of these investigations are described in *A Sourcebook for the Biological Sciences.*

Investigation 11-1
How do seeds respond to water?

The first step toward germination is the absorption of water, which is necessary for an increased metabolic rate. Even before any sprouts appear, the germinating seed becomes very active. Cells divide, grow, and begin to form organs such as roots, stems, and leaves. The rate at which water passes into the seed depends on the composition of its seed coat. The amount of water needed for germination depends on the structure and composition of the seed.

Activity time: 7 consecutive days for observations

Materials (3 groups of 3):
250 ml concentrated sulfuric acid
600-ml Pyrex beaker
6 Petri dishes
24 pieces of filter paper or 12 paper towels
3 ball-point pens
3 triangular files
180 unscratched seeds (minimum)
3 rulers
3 scissors
6 small plastic bags (sandwich size)

Preparation

If Petri dishes are not available, many alternatives can be contrived. Saucers or any small dish can be lined with paper and covered with plastic wrap. Even the paper alone can be put on plastic wrap, dampened, and loosely wrapped. (Be careful in Investigation 11-2 not to overheat plastic wrap in an incubator. There is no danger of melting at the recommended temperatures.)

Use any one of these species of seeds: black locust, *Robinia pseudoacacia;* honey locust, *Gleditsia triacanthos;* silk tree, *Albizzia julibrissin.* These seeds are available from:

Wood and Co., Inc.
2267 Lee Road
Cleveland Heights, Ohio 44118

The seed coats of these seeds resist the passage of water. If possible, have each group of students use a different species.

Several days before the Investigation begins, soak the seeds in water overnight. Use the seeds with undamaged seed coats. These seeds will not be swollen and will bounce from a metal surface with a ringing sound.

Place one third of the seeds in the 600-ml Pyrex beaker and pour the sulfuric acid *slowly* down the side, tilting the beaker to avoid splashing. Do not allow the students to handle strong acid. If you get acid on yourself, wash with a lot of water and with a solution of baking soda and water.

After 20 minutes, carefully pour off the acid into a glass bottle and store it for future use. Now fill the beaker with cold water. Do this rapidly to avoid injuring the seed embryos with the heat produced when acid dissolves in water. Pour off the water and rinse the seeds several more times. Spread the acid-treated seeds on paper towels and allow them to air-dry. Store the untreated and acid-treated seeds for each species in separate, labeled containers.

Since materials for this Investigation are similar to the materials for the next two Investigations, classroom efficiency can be improved by designating distinct areas of the room for each Investigation. Materials should be clearly labeled.

Analyzing data

1. The seeds will swell. You can infer that water has penetrated the seed coats.
2. Usually, the seeds that have a groove filed through their seed coats show the greatest increase in size and mass. They may begin to germinate on the third day. Acid-treated seeds show a definite, but smaller increase. The untreated seeds generally show little or no change.
3. Seed coats regulate the passage of water into the seed. When the seed coat is broken down, either chemically or physically, water penetrates faster. Acid-treatment dissolves the seed coat to an extent. Filing a groove in a seed provides an even more direct entry for water. Acid-treatment does occur naturally. The berries that birds eat are exposed to acid during the digestive process. These seeds usually survive and when excreted are more prone to germinate.
4. Seeds can survive longer if they have seed coats that resist the passage of water in either direction. This prevents drying out, and also prevents germination when too little water is available to sustain the seedling.

Investigation 11-2
How does temperature affect germination?

Most seeds germinate slowly at low temperatures. Yet several observations of seeds germinating on cakes of ice have been reported. Given other favorable conditions, the temperatures that facilitate germination often depend on the age of seeds. Generally, newly-matured seeds will germinate at lower temperatures than older seeds.

Among different kinds of seeds, response to temperature varies. Some will germinate only at cool temperatures, some only at warm temperatures, and some germinate equally well at both cool and warm temperatures. Certain seeds will not germinate at any constant temperature, preferring instead fluctuating warm-cold temperatures similar to local day-night temperatures.

Activity time: 7 consecutive days for observation

Materials (3 groups of 3):
9 Petri dishes
36 pieces of filter paper or 18 white paper towels

3 scissors
9 small plastic bags
refrigerator
1 or 2 incubators
3 thermometers
180 seeds of at least two kinds (minimum)

Choose at least two kinds of seeds from the columns below. Do not choose two kinds from the same column.

Column 1	*Column 2*	*Column 3*
peas (5)	turnip (3)	corn (4)
radish (4)	kohlrabi (3)	cucumber (3)
spinach (7)	cauliflower (3)	beans (5)
lettuce (7)	cabbage (3)	squash (4)
	broccoli (3)	pumpkin (4)

The seeds from Column 1 require cool soil to germinate. The seeds from Column 2 will tolerate cool soil but germinate best in warm soil. The seeds from Column 3 require warm soil to germinate. The numbers in parentheses represent the average germination time (in days) for each species.

Preparation

An inexpensive temperature-control unit that will maintain a constant temperature of 25°C or 35°C in a cardboard box can be purchased from scientific supply houses. Inexpensive brooder-type thermostats that can maintain constant temperatures in a wooden box can be purchased from mail-order houses and farm supply stores. Simple units can be constructed using light bulbs and cardboard boxes with holes for ventilation. For construction directions for more complex units consult:

> Barthelemy, Richard E., Dawson, James R., and Lee, Addison E. *Innovations in Equipment and Techniques for the Biology Teaching Laboratory.* Boston: D.C. Heath and Company, 1964, pp. 73–75.

Analyzing data

1. See Materials list.
2. The answer to this question will depend on what seeds the students study.
3. Plants that need a warm season to flourish will not germinate until warm temperatures prevail. Or plants in areas with short growing seasons will germinate in cool temperatures, taking advantage of the longest possible season.
4. Let students come up with answers. Some seeds may not be swollen. Other seeds may be swollen, but had lost their ability to germinate.

Investigation 11-3
Do seeds respond to light?

The presence or absence of light influences the germination of only a few kinds of seeds. Generally, in seeds affected by light, red light of a narrow range of shorter wavelengths promotes germination, while red light of longer wavelengths inhibits germination. The germination of California poppy and scorpion weed seeds is inhibited by the same wavelengths of light that promote germination in other kinds of seeds. The poppy and scorpion weed seeds also require a period of darkness for germination.

The light from one photographic flash bulb is enough to trigger seed germination in certain varieties of lettuce. On the other hand, the seeds of many grasses require repeated light exposures over a period of several days to stimulate germination.

Activity time: 7 consecutive days for observation

Materials (3 groups of 3):

6 Petri dishes or other covered containers
24 pieces of filter paper or 12 white paper towels
3 scissors
3 small, clear plastic bags
2 square metres of black plastic sheeting or black plastic from trash bags. Aluminum foil is also lightproof.
masking or transparent tape
1 lamp, preferably fluorescent
240 seeds (at least four kinds)

Use *Phacelia* (scorpion weed), at least one other kind of seed in Column 1, and at least two kinds in Column 2.

Column 1	*Column 2*
Grand Rapids lettuce	corn
salad bowl lettuce	cucumber
white burley tobacco	radish
evening primrose	wheat
Phacelia (scorpion weed)	pea

Phacelia is the only seed on this list whose germination is inhibited by light. The others in Column 1 are stimulated by light. Those in Column 2, plus most other vegetable seeds, are neither stimulated nor inhibited by light. It is best to obtain the light-sensitive seeds (Column 1) from a supplier who tests them periodically to assure their sensitivity.

Preparation

The black plastic sheeting can be taped to form lightproof bags. It is usually available at local hardware and garden supply stores. Be sure it is opaque and does not have holes in it. Aluminum foil can be used, but it rips more easily.

Analyzing data

1. Light or darkness is required for germination of some kinds of seeds; others are insensitive to light conditions. You could infer that seeds that need light to germinate should be planted on or near the soil surface; seeds that germinate in darkness should be buried.
2. Observation would require exposing the seeds to light.
3. No. You would need to vary the intensity and duration of exposure.
4. You would need controlled dark and light periods.
5. Some seedlings grown in the dark may not be as green as seedlings grown in the light.
6. You could make seven sets of Petri dishes and observe one every day for a week.

Many students may assume that water, heat, and light produce their effects independently. You can ask additional questions about germination in nature to develop the idea that a climate is a unique combination of precipitation, temperature patterns, and light conditions. Focus the discussion on the combination of factors that affect seeds.

Questions for further investigation

1. How much of a seed is necessary for germination?
2. How cold or hot can a seed get and still germinate? Will boiled or frozen seeds germinate?
3. If you took seeds that did not germinate in the refrigerator or incubator in Investigation 11-2 and then exposed them to room temperature, would they germinate?
4. Can germination be halted at various stages (by cooling, freezing, heating, changing light conditions, or acid-treatment) and then resumed? **Caution:** Do not let students handle the acid.
5. How much light (or darkness) does a seed need to germinate?
6. Will different colors of light affect germination differently?
7. Does depth of planting affect germination?
8. Would it make any difference if water were sprinkled over seeds like rain instead of being soaked up from underneath?
9. What conditions influence the growth of mold on seeds?
10. Are there chemicals that inhibit or stimulate germination?

Extend Your View 11-1
The best way to germinate seeds

If students do not bring in seeds, you could use any one of the seeds suggested in Materials for Investigations 11-1, 11-2, and 11-3 that students have not already used.

References

U.S. Department of Agriculture. *Seeds, the Yearbook of Agriculture.* Washington, D.C.: U.S. Government Printing Office, pp. 94–113 and 544–546. An authoritative reference on seeds and their germination requirements.

Salisbury, Frank and Parke, Robert V. *Vascular Plants: Form and Function,* 2nd ed. (Fundamentals of Botany Series) Wadsworth Publishing Co., Inc., 1970.

12 The water needs of plants

Behavioral Objectives

The students will learn
1. that both environmental factors and plant structure affect the rate of water loss from plants.

They will show they have learned
1. by identifying some variables that affect water loss in plants. (Extend Your View 12-1)

Overview

In Investigation 12-1, students gather data that shows plants lose water through their leaves. In Investigation 12-2, each group varies one factor, such as light, humidity, or the air movement across the leaves, and measures how the rate of water loss is affected. The combined class data yields considerable information on the factors that influence water loss in plants. In Investigation 12-3, students determine how reducing the number of leaves (leaf area) affects the rate of water uptake and loss from a single plant.

Background

Practically all life processes require water. Water is essential for chemical reactions such as photosynthesis. The minerals absorbed from the soil move in aqueous solution to the leaves. Substances manufactured by the leaves flow to where they will be used or stored. Water maintains the turgid or swollen condition of the cell. Internal water pressure (turgor pressure) contributes to the rigidity of the plant. Water is the major constituent of plants and is particularly abundant in young and growing tissues. Active tissues are 60 to 80 percent water while a dormant structure, such as a seed, may have a water content as low as 5 to 10 percent.

In spite of its essential role, only a small portion of water absorbed from the soil is actually converted by a plant. A large percentage of water escapes from the leaves and stems by a process called transpiration. The water loss serves two important functions: It maintains the moving column of water that transports materials upwards in the plant, and it cools the leaves. Students should understand that water loss is essential for plants to carry out some of their vital functions.

Although some water is lost from the stems of plants, most water loss takes place in the leaves. Five to ten percent of the water lost through the leaves evaporates directly through the surface. The rest of the water loss occurs through the gas exchange pores called stomata.

Investigation 12-1 Why do plants wilt?

In your classroom, because of supply and storage problems, it may not be practical to have all the students do Investigation 12-1. The activity can be done as a demonstration, followed by a class discussion. Or one group of students can work on this activity while the rest of the class is finishing "What influences seed germination?".

Try to help the class see wilting as a lack of support. You could demonstrate the reverse of this process by standing a stalk of wilted celery in a glass of water.

As an alternative to this Investigation, you might have students qualitatively determine where water loss occurs in plants. Cobalt chloride paper turns from light blue to light red in the presence of moisture. Have students clip or tape small pieces of cobalt chloride paper to the stem and both upper and lower surfaces of leaves. Then they can determine which papers turn color and in what order. The paper attached to the underside of the leaves should turn color first, followed by the upper surface, then the stem.

Be sure to prevent exposure of the cobalt chloride paper to other moisture. If it turns light red before application to the plants, heat the paper over a hot plate or burner until it returns to its blue color.

Activity time: 30–45 minutes
Setting up (first day): 20–30 minutes
Taking measurements (second day): 10–15 minutes

Materials (groups of 7):
12 potted plants, 12–15 cm high
1 wilted plant
4 plastic bags to cover pots
4 larger plastic bags to cover entire plants
8 rubber bands or wire ties
2 or 3 double beam balances, 500-g capacity
masking tape
4 marking pens

Preparation

Coleus, nasturtium, geranium, begonia, or philodendron can be used in this Investigation. These plants

can be purchased from a nursery or supermarket. Do not water one of the plants for several days in advance. Since the amount of water that evaporates through the porous walls of clay pots is significant, it is better to use plastic pots or paint the clay ones.

Analyzing data

The emphasis should be on measuring water loss itself, rather than on the causal mechanism. Students should determine that plants lose water through their leaves.

Plant A should lose the most mass, Plant B the next, and Plant C the least, if any. In an experiment with a plant that had a mass of 150 grams (pot and soil included), after 24 hours Plant A had lost 12 grams, Plant B had lost 2 grams, and there was no noticeable change in the mass of Plant C.

Investigation 12-2
What environmental variables affect water loss in plants?

In this Investigation, each group of students decides which variable to study. You will need to help the students adapt their experimental designs to the available supplies, classroom space, and time.

Activity time: 2–3 class periods, depending on student interest and available materials

Materials (groups of 4):

2 or 3 plastic dishpans or buckets
1 knife, pruning shears, scissors, or razor blade
2 litres boiled water
7 ring stands, rings, and wire gauzes
7 support clamps
3 metres capillary tubing, 0.5- to 1.0-mm bore
7 5-cm pieces of rubber or plastic tubing (thin-walled, high quality tubing)
7 10-cm pieces of soft wire
7 250-ml beakers or wide-mouthed jars
7 leafy branches or tops of small plants with woody or rigid stems. (Evergreens work best; fresh branches of woody shrubs, such as willow or privet, also give rapid results.)
7 rulers
transparent tape
paper towels
petroleum jelly

Some of these items will be needed when students investigate different variables:
250-watt fluorescent or incandescent lamps
clear plastic sheeting, plastic bags, or aluminum foil
electric fan
electric heating tape (the kind used to warm plumbing pipes)
thermometers
sponges
Humidity Indicator Cards, range 10–100 percent
calcium chloride or silica gel for a dessicant
photographic light meter (optional)

Preparation

Cut the capillary tubing into 30-cm lengths and fire polish the ends to prevent cuts. Lubricate the glass tubing. Grasp it in one hand and the rubber tubing in the other. Rotate and push them gently together. Never press down hard on the glass tubing to force the pieces together. Wrap the glass tubing with a cloth as an added safety precaution.

Order several Humidity Indicator Cards from:

Humidial Company
P.O. Box 464
465 Mt. Vernon Street
Colton, California 92324

Select branches from vigorously growing shrubs or trees. One or two branches of the same kind will be needed per group. Stems should be 4 to 5 mm in diameter. For best results, branches should be cut the day they are to be used. Immediately after cutting, the ends should be placed in a container of water and kept there until the potometer is prepared. If air is allowed to enter the cut end of the stem, the transport system may become blocked.

Analyzing data

Plants will tend to lose water most rapidly under hot, dry, and windy conditions. Help students compare experimental results to the behavior of plants in a natural environment. If one group finds that plants lose more water when humidity is low, ask "What kinds of natural environment have conditions of low humidity? How would this affect the numbers and kinds of plants that can live there?" Or, "Do you think low humidity and high winds might cause more water loss than high humidity and high winds?"

Investigation 12-3
Does the number of leaves affect water loss?

Activity time: 1–2 class periods, depending on the type of branches used

Materials (groups of 4):

7 bubble potometers from Investigation 12-2
7 leafy branches or tops of small plants with rigid stems

Plants and potometers from Investigation 12-2 may be used the same day for Investigation 12-3 if time permits. If the same plants are used, make sure students

keep the ends of the tubing in the water. If Investigation 12-3 is to be done the next day, new branches will be needed.

Analyzing data

1. Depending on environmental conditions, a single plant can have a wide range of water uptake and loss rates. The student data should show that reducing leaf area reduces water loss. Discuss the relationship between reducing the number of leaves and reducing the total surface area of the leaves. Some students might want to investigate that idea by using plants and stems with different types of leaves. Suggest that they repeat Investigation 12-1 as a beginning.
2. This Investigation should lead to some understanding of plant adaptation to arid areas and dry seasons. For example, winter can be thought of as a dry season when the ground is frozen. Deciduous trees minimize transpiration when they lose their leaves in winter.

   One common plant adaptation to dry areas is a reduction in surface area. For example, in the cacti, leaves have been reduced to spines. Shrubs from arid areas, such as the creosote bush, also have fewer and smaller leaves. Try to have cacti available for examination or testing.

   Discuss the affect of reduced leaf area on the rate of photosynthesis. Ask students how plants like cacti can carry on photosynthesis when their "leaves" or spines do not contain chlorophyll. In such plants, photosynthesis takes place in stems and branches.
3. The larger the leaf, the greater the leaf area, and the greater the potential water loss.

Films

Water and Desert Plants. BSCS Single Topic Films. Houghton Mifflin Company, Boston, Massachusetts.

13 Coyotes and their prey

Behavioral Objectives

Students will learn

1. that the balance of a complex food web is easily disrupted.
2. that any solution to an ecological problem involves a compromise between conflicting interests.

They will show they have learned

1. by predicting what happens when a food web is disturbed. (Extend Your View 13-1)
2. by evaluating a proposed solution to an environmental problem after considering the needs of the organisms involved. (Extend Your View 13-2)

Overview

Students are presented with the problem that arises when people interact with coyotes. The students analyze descriptions and quantitative data on the ecological role of the coyote. Students are introduced to the concepts of community, food chain, and food web. Then they decide if a proposed solution to the coyote problem is reasonable.

Background

The coyote problem is a case of competition between people and coyotes for chickens and livestock. People believe that they should regulate the competition. They want to control the coyote population to suit their needs. Some people who campaign against coyotes probably misinterpret the predator-prey relationship. Predation is a natural and essential step in the transfer of energy through a food web. But people often associate predation with the stereotype of the strong attacking the weak—cat and mouse, or hawk and sparrow.

Predation must be studied in terms of communities or populations, not individuals. A predator population helps control the size and quality of prey populations. Predation tends to remove prey that are physically unfit. In the absence of predation, some populations grow to a size far larger than the environment can support. Then disease and starvation may nearly wipe them out. Populations of rabbits and rodents seem to require predation for stability.

Predation is only one of many interacting variables that affect population size. Members of a population also compete with each other for a limited amount of food, space, and chance to reproduce.

Populations are also regulated by factors that are independent of predation or the population density. For example, good growing weather can increase the food supply and decrease the number of deaths by starvation. People may also alter populations by changing the landscape or spreading pesticides.

The problem of coyote control is compounded by interspecific competition. Livestock and rodents are competing for the grass, just as coyotes are competing with people for the livestock. Generally, the greater the competition between two species, the less chance that both can exist in the same habitat. One of the species may become extinct or migrate out of an area.

Investigation 13-1
The coyote problem

During the late sixties and early seventies there was growing criticism about the control of predators by sheep ranchers and the United States government. There were attempts to define the problem and find the best solution. During this time there was an increasing awareness of the predator as a necessary part of the ecological balance.

Until 1972, control programs were based on a 1931 law that authorized the Secretary of Agriculture to carry out a cooperative program for the eradication, suppression, or control of predators. The *Cain Report,* which studied the problems of predator control, prompted President Nixon to issue an Executive Order banning the use of cyanide, strychnine, and 1080 on federal lands used for grazing. On March 10, 1972, the Environmental Protection Agency suspended registration of these chemicals for predator control on any lands. This ruling stopped interstate shipments of the chemicals.

Two bills were introduced in Congress in 1972. One would have authorized the Secretary of Agriculture to indemnify farmers who could prove, in writing, losses due to predators (HR 14158). But criteria for determining such losses could not be established and the bill was never passed or reintroduced.

The other bill (HR 13152) passed the House but had to be reintroduced in 1973 as the Animal Damage Control Act of 1973. Basically, this act put into law the Executive Order and EPA's directive on the use of poisons for predator control.

The purpose of this Investigation is to have students consider if the proposed law is a reasonable solution to the problem. The letters included in this Investigation were modeled after testimony given during the hearing on the Animal Damage Control Act of 1972 and 1973. They do not represent the opinions of all the members of the special-interest groups presented in this Investigation.

Activity time: 3–4 class periods
Gathering data: 40 minutes
Analyzing data: 2–3 periods

Discussion

During the final discussion you might ask students if ranchers should adapt to the habits of coyotes by using different ranching practices. Here are some practices that students might suggest.

1. Keep chickens in enclosures.
2. Pen and guard sheep, especially lambs in spring.
3. Do not discard dead animals where coyotes can find them and develop a taste for the meat.
4. Use special measures such as floodlights and extra guards during times when predation is greatest.
5. Bring cows in from the range—or guard them —when they calve.

These practices may require additional time, money, and personnel. Some farmers or ranchers may not be able to afford the additional safeguards.

Analyzing data

1. The students may decide that some of the reasons for continuing the old program were not based on reliable data, for example, data on the coyote diet. The new data may convince the students to pass the proposed law.
2. Voting to pass the law implies a belief that the new law will help solve the coyote problem.
3. With the ban on poisoning, there might be a temporary increase in the coyote population until a new balance is reached. For a while the coyote problem might worsen. In Part B, it would be difficult to define "serious damage." Part C would be difficult to enforce without reliable criteria for establishing the cause of death in sheep.
4. Some of the terms should be more clearly defined. Students might suggest a phasing out of the present program rather than a sudden abolition. Phasing out might eliminate the possibility of a worse coyote problem right after the law is passed. Some students may suggest enacting the law only after a new control method is found.

References

Gier, H. T. *Coyotes in Kansas,* rev. ed. Manhattan, Kansas: Agricultural Experimental Station, Kansas State University, Bulletin 393, 1968. A thorough

examination of coyote behavior. The source for some data for this Investigation.

Gustavson, Carl R. and Garcia, John, "Pulling a Gag on the Wily Coyote." *Psychology Today,* August 1974. The source for Extend Your View 13-2.

Howard, Walter E., "Predator Control: Whose Responsibility?" *Bio Science,* June 1974. Explains who is responsible for predator control, as well as legislation and other developments in the area.

McMahan, Pamela, "The Victorious Coyote." *Natural History,* January 1975. Discusses the coyotes varied adaptive mechanisms that have allowed the species to survive and to extend its range.

Olsen, Jack. *Slaughter the Animals, Poison the Earth.* New York: Simon and Schuster, 1971. Emphasizes the profit motivation in the way stockmen, ranchers, and government officials have worked together to control predators.

Olsen, Jack, "The Poisoning of the West." *Sports Illustrated.* March 9, March 15, and March 22, 1971. Excerpts from his book.

Ryden, Hope, "The Lone Coyote Likes Family Life." *National Geographic,* August 1974. The author relates her own experiences with coyotes. She describes their social behavior in a relatively undisturbed environment.

14 Competing with microorganisms

Behavioral Objectives

The students will learn

1. that microorganisms cause organic materials to decay.
2. that people must treat their food to protect it from microorganisms.
3. that treating food to prevent decay could have undesirable effects.

They will show they have learned

1. by recognizing some signs of decay. (Extend Your View 14-1)
2. by identifying conditions that inhibit the growth of microorganisms. (Extend Your View 14-2)
3. by predicting the desirable and undesirable effects of preserving food. (Extend Your View 14-3)

Overview

Investigation 14-1 provides students with evidence that microorganisms are responsible for food spoilage. In Investigation 14-2, students go into their community to gather data about the techniques and costs of protecting food from microorganisms. Students also gather data on the reasons for and the cost of food additives. In Investigation 14-3, students observe a demonstration of decaying materials and discuss possible disadvantages of preventing decay.

Background

The term microorganism can be applied to protozoa and bacteria, as well as some forms of fungi and algae. These Investigations deal mainly with bacteria and molds (forms of fungi). Microorganisms interact with people in many ways. Some of these interactions are harmful while others are obviously beneficial. Microorganisms are considered harmful when they live on animals and plants and cause diseases. Microorganisms are also considered harmful when they consume people's food supply.

Microorganisms that obtain nourishment from organic matter (generally bacteria and fungi) are responsible for recycling important elements in the environment. For example, as animals respire, part of the carbon from the food is returned to the atmosphere as carbon dioxide. But much of the carbon remains bound in the bodies of plants and animals. When an organism dies, decomposition makes this carbon accessible to new organisms. Microorganisms also play major roles in the recycling of nitrogen and sulphur. Microorganisms help keep essential nutrients in circulation.

When decomposition occurs to objects people wish to keep, it is considered undesirable. When decomposition operates on waste products, people consider it desirable and promote the process. Microorganisms are controlled by subjecting them to injurious chemicals or unfavorable physical environments. Some of these conditions actually kill the organisms while

others inhibit metabolic activity and growth. Growth of microorganisms is commonly controlled by these techniques:

1. Regulating the temperature. Very high temperatures kill microorganisms. High-temperature steam is usually most effective. Lower temperatures, including freezing, generally inhibit growth.
2. Dehydration. Microorganisms cannot grow without water. Storing foods under high concentrations of salt or sugar causes water to flow out of the cells, inhibiting the growth of microorganisms. Ham and canned fruits are stored that way. This technique, as well as the complete drying of food, does not always kill microorganisms. Microorganisms that can form spores can survive these conditions.
3. Treating with radiation. Objects to be sterilized are exposed to gamma radiation to kill microorganisms. For food preservation, this technique is largely at the research stage.
4. Treating with chemicals. Substances such as phenols, alcohols, spices, heavy metals, dyes, acids, and alkalis are commonly used.

Investigation 14-1
Why does food spoil?

Activity time: 3 class periods
Setting up: 1 class period
Observing results: 10–15 minutes for the next two days. It will take three days for the meat to decay. Students can begin Investigation 14-2 while they are waiting to complete Investigation 14-1.

Materials (groups of 4):

¼ lb. (112 g) fresh hamburger or other ground meat
14 test tubes (16 × 150 mm) with cotton or foam plugs Plugs allow gases to escape but keep out molds and bacteria.
7 test tube racks
7 spring-type test tube clamps
7 burners (alcohol burners are acceptable)
7 600-ml Pyrex beakers or metal pans (fewer can be shared)
7 stands with wire gauze
7 glass-marking pencils, or masking tape and felt-tip pens
7 medicine droppers
7 microscopes with at least 43× objectives
21 microscope slides
21 cover slips

The size of the student groups will be determined by your supply of test tubes and the availability of microscopes.

Analyzing data

1. The meat is no longer of uniform shape and consistency. The color has changed. Gas bubbles and a penetrating odor are noticeable.
2. You can infer that the boiled hamburger is not decaying because boiling killed the microorganisms. You can also infer that the cotton plug keeps new microorganisms from entering.
3. Foods that are not frozen will probably last longer if they are cooked. Decay occurs most quickly in fresh foods. Those who handle foods should be aware that dirty hands carry more microorganisms than hands that have been washed.

Investigation 14-2
Do microorganisms cost you money?

This Investigation is done as homework. Preparation for the interviews and subsequent discussion can be done in class while you are waiting for the results of Investigation 14-1.

Demonstration

You can prepare biscuits to show that, as the concentration of one food additive is increased, the ability of microorganisms to break down the food decreases. The federal regulation states that a maximum of 0.32% propionate per mass of flour may be used for white bread, 0.38% for whole wheat bread, and 0.3% for cheeses.

Preparation

Either you or your students can prepare biscuit dough, using this recipe.

2 cups (285 g) flour
3 tsp (9 g) baking powder
½ tsp (2 g) salt
¼ cup (60 g) shortening
¾ cup (180 g) milk

Mix the flour and baking powder in a bowl. Cut in the shortening with a fork or pastry cutter until the mixture is like coarse crumbs. Add all the milk at once. Stir quickly with a fork. Turn the dough onto a lightly-floured surface. Knead gently for 10-12 strokes.

Measure out 10 grams of sodium or calcium propionate. Separate the dough into 8 equal parts. To one part add *no* sodium or calcium propionate (0%). To the second add 0.05 g (0.1%); to the third, 0.1 g (0.3%); to the fourth, 0.2 g (0.6%); to the fifth, 0.4 g (1%); to the sixth, 0.9 g (2.5%); to the seventh, 1.8 g (5%); and to the eighth, 3.6 g (10%). Knead all the portions well and then shape into biscuits, 2 cm thick. Bake on a cookie sheet for 10–12 minutes at 450°F.

After the biscuits have cooled, cut each one in half. Prepare the biscuits in a pan using either Method 1

or 2 under Preparation for Investigation 14-3. The untreated biscuits will begin to show mold growth in about three days.

Analyzing data

1. Dry processed foods will probably last longest. Moisture helps to increase the rate of decay. Vacuum-packed canned goods also last a long time. Fresh fruits, vegetables, and meat are the most perishable.
2. Cooking, canning, adding preservatives, drying, and freezing.
3. These answers will depend on the type and size of the store the students visit. Generally, however, the loss is passed on to the consumer, as are the costs of processing and packaging.
4. This again depends on the size and patronage of the store. Large turnover of foods means fewer problems with spoilage. Some stores that prepackage their products sometimes include a few undesirable items in with the good produce. Present consumer legislation seems to be partially correcting this problem.
5. Processed foods are usually more expensive than unprocessed foods because of the cost of the additional steps. However, since unprocessed foods may spoil faster and the price of this spoilage is passed on to the consumer. the students may find that unprocessed food is as expensive or even more expensive than processed food.
6. Natural foods generally cost more, because no additives means more rapid decay and because the quantity of natural foods sold is smaller.
7. Food preservation gives people the advantage in the competition with microorganisms. At the experimental level, radiation appears to be a very effective method of preservation, as is dehydration. Refrigeration and boiling seem to be more limited in their effects.

Help students focus on the consumer costs that result from microorganisms interacting with humans. The discussion could lead to a consideration of other serious issues such as the effect of food treatment on the taste or texture of foods, or the effects of food additives on health.

Additives as a potential health hazard is not discussed in the text because of the difficulties in interpreting relevant data. The economic issue of chemical additives, however, can easily be discussed. The consumer usually wants to spend less time preparing meals. Therefore, more foods are being processed to reduce preparation time. Various preservatives, flavor enhancers, and texturizers must be added to compensate for those substances "processed out" of the foods.

Investigation 14-3
The rate of decay

Activity time: 40–45 minutes

Materials (class):

soil (not sterilized)
garbage
large, clear plastic pan
glass plates, plastic wrap, or aluminum foil

Preparation

To get satisfactory results, the decomposing garbage must be set up at least 2–3 weeks before the Investigation is done.

Method 1 Add a variety of materials to a layer of wet soil in a pan (Figure 14-1T). You can use:

1. fruits, vegetables, and meat
2. plastic objects
3. metal objects, such as aluminum foil or nails
4. glass, for example, pieces of a broken bottle

Be sure to take photographs of the setup to show the condition of the materials. Or have duplicates of the materials available at the time of the demonstration. Cover the materials with a few centimetres of wet soil. Set the container in a warm place. Cover the pan with some plastic wrap or aluminum foil to prevent the soil from drying out. Just before class, remove the top layer of soil. Recover the pan with plastic wrap or a sheet of glass to contain the odor.

Figure 14-1T

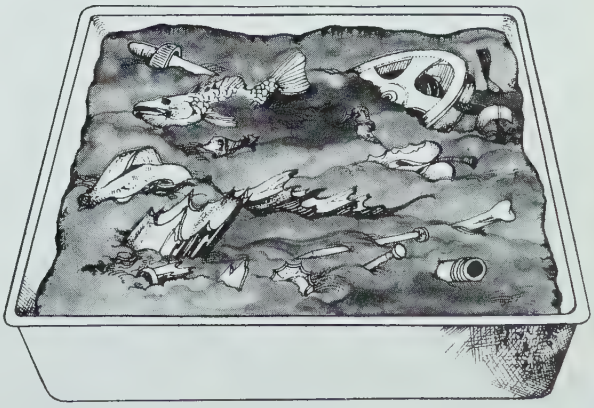
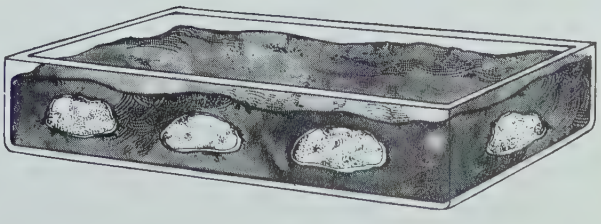


Figure 14-2T



Method 2 For this method you need a clear plastic or glass pan, or aquarium with straight sides, at least 10 cm high. Place the various materials against the glass sides. (If using biscuits, place the cut side against the side of the container as shown in Figure 14-2T.) Fill in with soil around and behind the materials. Cover the pan with a glass plate, plastic wrap, or aluminum foil. Keep in a warm place. Using this method, you need not uncover the pan for observation.

Analyzing data

1. The fresh foods will probably show the most rapid change, followed by the processed foods or foods with additives. Metal objects may begin to show signs of rust if they are made of iron or steel. Even though this is not a process of decay, students can begin to realize that various objects can break down, though slowly, and reduce accumulation.
2. The resources on this planet are finite. When objects decay, their components are recycled. Preservatives interfere with recycling. "Premature" recycling of food (spoiling) or cars (rusting) is undesirable.

   Discuss other ways of interrupting decomposition. The production of some materials, such as plastics, effectively blocks the carbon cycle by tying up carbon in forms that do not break down readily. Such nonbiodegradable materials accumulate in the environment. The present trend is to produce synthetic products that are biodegradable and can be recycled.

References

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15 Organism versus organism

Behavioral Objectives

The students will learn

1. that antibiosis is a common type of interaction between organisms.
2. that the production of an antibiotic by an organism may help that organism survive.

They will show they have learned

1. by designing an experiment to explain an interaction between organisms. (Extend Your View 15-1)
2. by inferring how substances produced by organisms are related to their survival. (Extend Your View 15-2)

Overview

Students will be introduced to antibiosis through a puzzling situation, an antibiotic interaction between two species of seeds. They will discuss the situation and make hypotheses that may explain their observations. Some students will design experiments to test these hypotheses. Simultaneously, the rest of the class will conduct a variety of investigations. They will look for antibiotic interactions involving seeds, bacteria, molds, and other organisms.

Background

In this Investigation, antibiosis is broadly defined as the interaction of two organisms in which one produces a chemical substance, called an antibiotic, that injures or kills the other organism. According to this definition, many kinds or organisms participate in antibiotic interactions. A classic example, and one most likely to be familiar to students, is the mold *Penicillium,* whose secretions kill or inhibit the growth of some species of bacteria. Poisonous snakes, lizards,

and spiders also use antibiosis. They kill their prey and defend themselves with venom.

When antibiosis is viewed in a broad sense, it becomes apparent that this interaction, which pervades the living world, is an important form of adaptive behavior. The production of antibiotics may help one species compete successfully with other organisms for food, water, or territory. Or it may protect the organism from disease or predation.

Investigation 15-1
Offense and defense

Activity time: 5 class periods
Demonstration and planning experiments: 2 class periods
Setting up experiments: 1 class period
Analyzing data: 2 class periods

Some of the results take 3 days (growth of molds) to become visible. It would be best to set up the experiments on a Friday to take advantage of the weekend. There are so many possible tests that students could work individually on separate investigations. Or some might prefer to work in small groups. Those working with bacteria might find techniques easier to manage if they work in pairs.

Materials (demonstration, groups of 5):
radish or cucumber seeds (A 3-g packet contains enough radish seeds for about 17 dishes, or cucumber seeds for about 6 dishes.)
Merion bluegrass seeds (A 35-g packet contains enough seeds for about 10–15 dishes, including extract preparation.)
18 Petri dishes
36 filter paper circles, 10-cm diameter

Preparation
Each exhibit (Figure 15-1T) consists of 3 Petri dishes in which seeds are "planted" about 4 or 5 days in advance. Use two sheets of filter paper per dish. Unsoaked grass seed should cover most of the filter paper surfaces in Dishes B and C. Dishes A and C should each have about 20 radish or 10 cucumber seeds. Soak the remaining grass seeds (about 30 g) in 130 ml of water overnight. Filter out the seeds and add the extract to each Dish C instead of tap water. There will be enough extract for about 10–15 dishes. The same exhibits can be used for all classes if the seeds are not disturbed.

Discussion
The difference in radish seed germination in Dishes A and C should elicit questions. For example, students may ask if two kinds of seeds were used, or if the seeds were treated differently. Answer questions like these. Students will probably infer that the grass seeds are affecting radish seed germination.

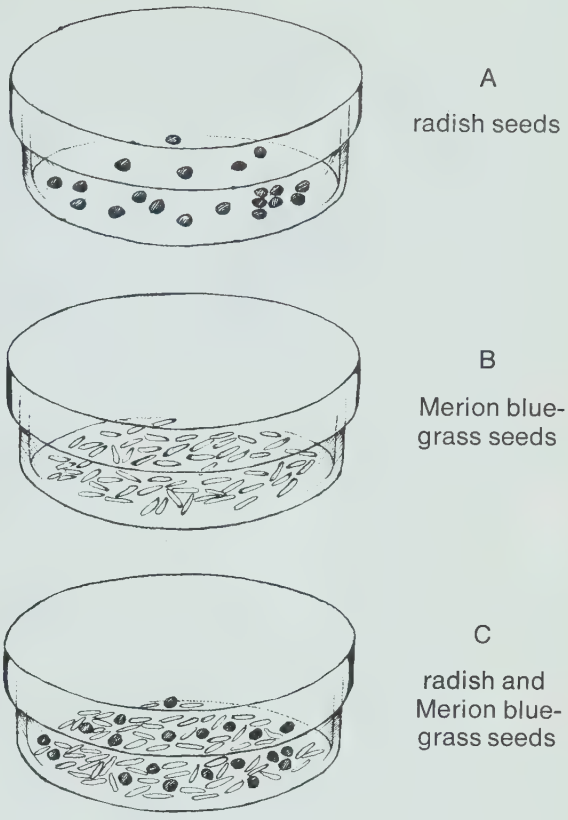


Figure 15-1T

Student questions and inferences will suggest experiments to get further data on the germination exhibit, and to look for antibiosis between other organisms. The class discussion should focus on:

1. The identification of investigable questions.
2. Designing some general procedures for identifying antibiotic interactions and the possible source of antibiotics. For example, if a substance from seeds is suspected of affecting other seeds, water extracts of the seed contents (instead of the seeds themselves) can be mixed with other organisms.

Materials (teacher):
1 microbiological inoculating needle or loop
pressure cooker or oven
1 roll bacteriological plugging cotton (nonabsorbent)

Materials (class):
All students will not be using all these materials and equipment. However, it is likely that most will receive some use. Exact quantities will be determined when the students plan their investigations.

nutrient agar (4 oz. will make about 400 Petri dish cultures)

nutrient broth (4 oz. will make about 500 test tube cultures)
bacteria and molds (subcultures of each):
Sarcina subflava
Bacillus subtilis
Bacillus brevis
Streptomycus venezuelae
¼ lb. Merion bluegrass seeds
radish seeds (A packet contains about 700 seeds.)
cucumber seeds (A packet contains about 130 seeds.)
several packets of one or two of these varieties:
parsley, celery, clover, dill, carrot, parsnip, wheat. (Except for clover and wheat, all belong to the carrot family.)
fresh roots, several varieties:
carrot, horseradish, parsnip, dandelion (purchased, or dug up)
2 or 3 fresh onions
1 or 2 garlic cloves
12–24 squares of old, but clean nylon stockings, 20–30 cm square
several dozen test tubes, 10 × 75 mm or 16 × 150 mm with cotton or foam plugs
Petri dishes, plastic or glass
2 or 3 burners
1 bottle of liquid chlorine bleach, such as Clorox, containing 5.25% hypochlorite (optional)
hot plate (optional)
2 or 3 alcohol lamps (optional)
12 medicine droppers, at least 10 cm long
several small packages of cotton swabs, 15 cm long
500 ml of 70% ethyl or isopropyl alcohol
2 or 3 thermometers
incubator or constant temperature box (capable of maintaining a temperature between 37–42° C)
2 jars (one labeled "Used Swabs" and one labeled "Used Droppers")

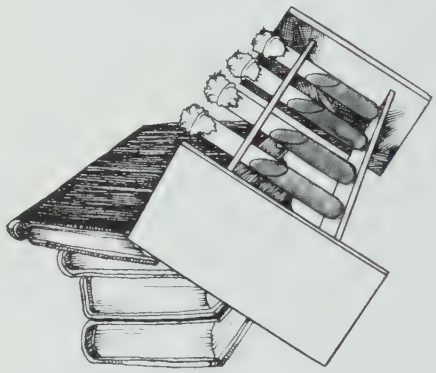
Preparation

Bacteria and molds One purchased culture of each bacteria and mold can be the source of subcultures for all classes. Cultures can sometimes be obtained without cost at local high schools, colleges, or universities if you supply the sterile medium. Subcultures for teacher use can be made on nutrient agar slants or in nutrient broth. Subcultures can be kept in the refrigerator for several weeks.

Directions for preparing media are given on each container. Fill several dozen test tubes no less than half full with nutrient agar. The class will remelt these to pour Petri dish cultures. Fill other tubes half full of broth for subculturing the organisms that students will use. It is easier for students to transfer organisms from broth than from agar slants. Avoid leaving any medium near the mouth of the tubes.

Sterilize the students' agar and the broth as well as the tubes for your own slants at 15 pounds pressure for 15 minutes. Stand the tubes upright so that the medium does not touch the plugs. Remove the tubes when the medium is still hot, but the pressure has dropped to zero. Slant the tubes with liquid agar for your own cultures until the medium hardens. This procedure is shown in Figure 15-2T. It is not necessary to slant the agar if the medium is to be poured into Petri dishes. Keep the broth tubes upright.

Figure 15-2T



To prepare subcultures, work near the flame in a place with a minimum of air currents. If you find the techniques difficult to manage by yourself, have a student help by removing the plug. Refer to Figure 15-3T.

Sterilize (heat to red-hot) an inoculating loop in a low flame. Hold the loop so the flame heats as much of the wire as possible. Remove the plugs and heat the open mouths of the culture-containing tube and a sterile agar tube for about five seconds. Keep all tubes slanted during the transfer so any contaminent falling into the tube will stay near the lip and be sterilized. Reflame the loop and insert it into the tube without touching the glass. Touch the loop to a clear area of agar. This cools the loop immediately without chance of recontamination. Then pick up a small amount of the culture and streak it on the sterile agar. Gently slide the tip of the needle along the agar surface without breaking through. Immediately reheat the tubes and plug them; then sterilize the needle.

Place the inoculated agar slants in an incubator. Incubate the cultures at 37°C. One tube of each should be enough for at least five groups of students. The subcultures should be visible within 48 hours.

Just before the bacteria are used, wash off the visible growth from agar slants by pouring 5 ml of saline solution over each slant. Dislodge the bacterial

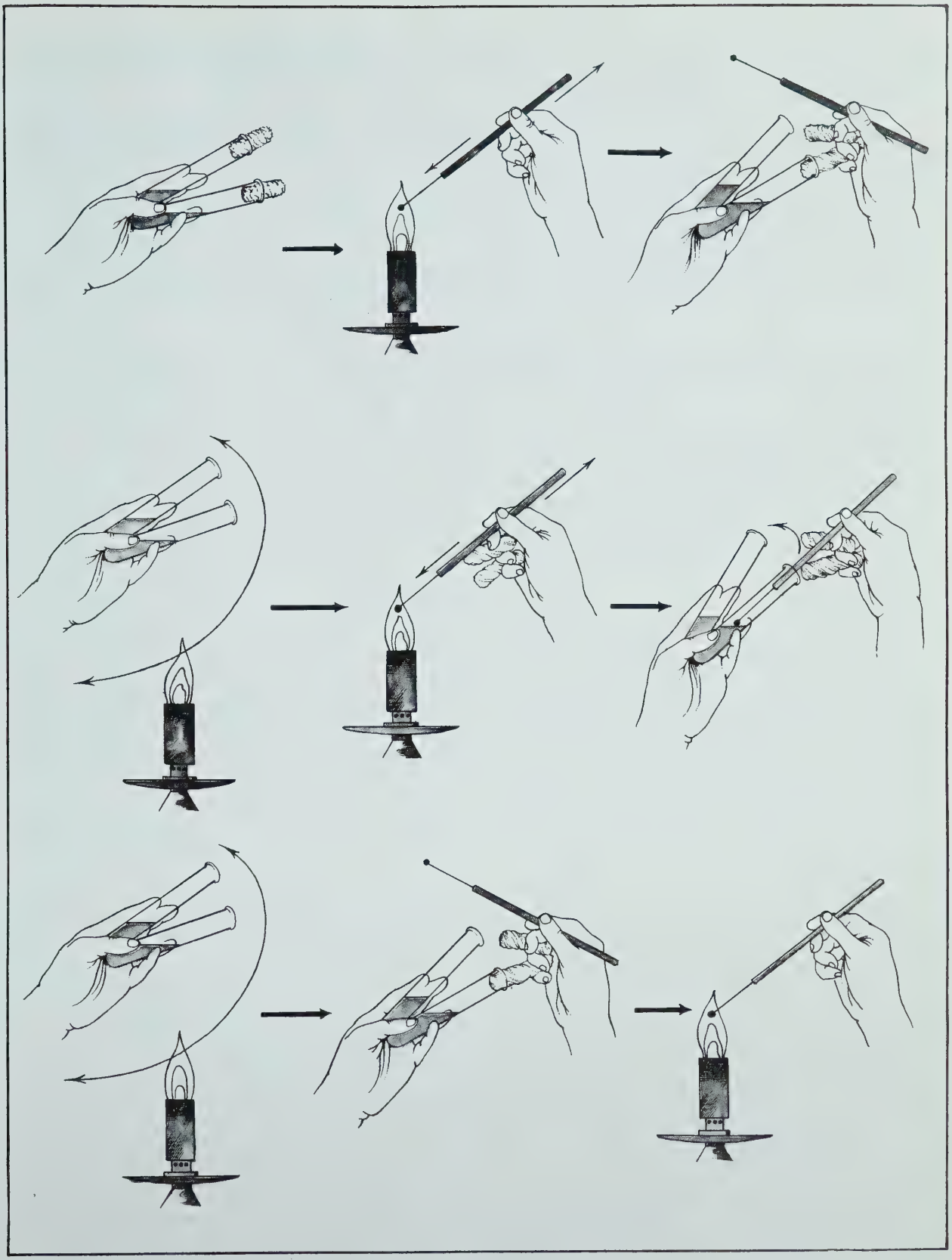


Figure 15-3T

growth by gently agitating it with an inoculating needle. Try not to break through the surface of the agar. Pour off the suspensions of cells into separate, labeled, clean 125-ml Erlenmeyer flasks. Gently shake the flasks to break up clumps of growth. The liquid should be very cloudy. Hold each flask up to the light, placing a pencil behind the flask. Add more saline until the pencil point can barely be distinguished through the liquid.

Sterility is not important when tears and saliva are used. Antibiosis is obvious in less than 24 hours, or before contaminant microorganisms become apparent.

Saline Solution To make the saline solution, dissolve 2.1 g of non-iodized salt (sodium chloride) in 250 ml of distilled water.

Petri dishes Sterile plastic dishes are preferred. Do not sterilize plastic dishes in an oven. Contaminated dishes can be reused, if necessary, after cleaning and soaking in alcohol for several minutes. Alcohol-soaked dishes should be dried by inverting them on *clean* paper towels. Plastic dishes can also be resterilized by soaking them for at least 2 hours in 0.1% hypochlorite solution. Make this by adding 20 ml of chlorine bleach solution to 980 ml of water.

Glass Petri dishes can be dry-sterilized in an oven at 350–400°F (175–205°C) for at least two hours.

Cotton swabs Most packaged cotton swabs are already sterile. After a box has been open to the air for a class period, the swabs should be considered contaminated. Unless they have plastic sticks, resterilize the swabs in a pressure cooker in large, plugged test tubes or flasks at 15 lbs. pressure for 15 minutes. Or roll the swabs in foil and place them in the oven at 350–400°F (175–205°C) for at least two hours.

Alcohol 70% ethyl or isopropyl alcohol is available from local drugstores. It can also be made by mixing three parts (by volume) of 95% alcohol with one part of water.

Analyzing data

There will be a wide range of results depending on the organisms used. For example, clover seeds will probably not germinate when planted with carrot or celery seeds. Tears and saliva should show striking antibiosis with bacteria.

Focus the discussion on the survival value of antibiosis. Also discuss other defense mechanisms such as camouflage, imitation, and bluffing.

References

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Stong, C. L., "The Amateur Scientist." *Scientific American,* April 1962. Experiments with plant-growth inhibitors.

Stong, C. L., "The Amateur Scientist." *Scientific American,* November 1965. How to isolate, from topsoil, microorganisms that secrete antibiotics.

Sussman, Alfred S. *Microbes: Their Growth, Nutrition and Interaction.* Student Edition and Teacher's Supplement. Boston: D.C. Heath and Company, 1964. Detailed laboratory experiments on antibiosis.

Went, Frits, "The Ecology of Desert Plants." *Scientific American,* April 1955. Discusses the interrelations of rainfall, roots, and seed inhibitors in desert plants.

16 Planet management

Behavioral Objectives

The students will learn

1. that the selection of goals is a prerequisite for making management decisions.

They will show they have learned

1a. by selecting some ideal conditions or goals for the management of a planet. (Extend Your View 16-1)

1b. by using goals to choose between two projects for solving the same problem. (Extend Your View 16-2)

Overview

This Investigation centers around *The Planet Management Game,* in which the students experiment with managing an imaginary planet. The management team must decide how the planet's budget will be spent for 10 consecutive five-year periods. After a few preliminary rounds, the goals or ideal conditions are determined. Projects are then evaluated with these goals in mind.

Feedback data from Clarion is provided at the end of each five-year period so that the management team may continue or change its projects. The data is based on current knowledge of population growth, food production, and the impact of development projects on the environment. This Investigation raises many questions about the management of Planet Earth, the subject of Unit Four. The questions for class discussion at the end of the Investigation build a bridge to that unit.

Background

Most of our present knowledge about population growth has been based on data gathered from laboratory colonies of small organisms. It is believed that much of this knowledge also applies to people, although certainty can never be attained.

Population size is a function of time for a species in a closed system. In recent years, the idea that the whole earth should be treated as a more-or-less closed system has received strong emphasis.

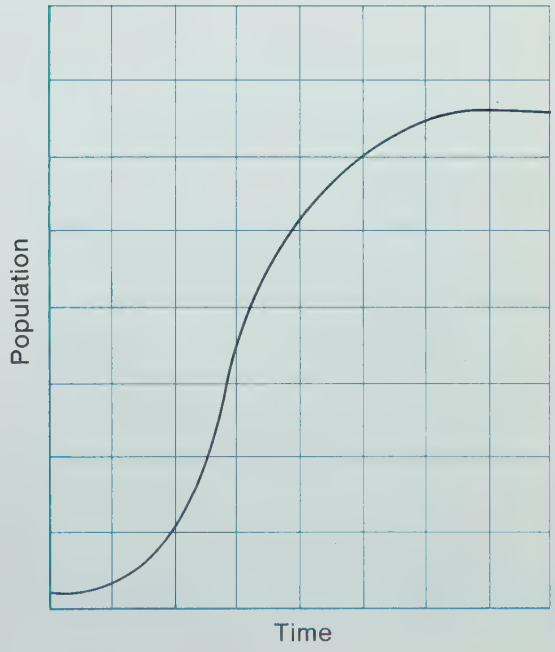
If the population of people on Earth is described by the graph in Figure 16-1T, it is difficult to know where we are on the time scale. Most estimates place the present on the steepest part of the graph. If the present trend continues, human population will increase until some limiting factor causes the population to level off—or crash.

If food is the limiting factor, when the population does level off, the amount of food available per person (on a worldwide basis) will be less than it is now. (Of course, this does not mean that the food will be any more evenly distributed than it is now, unless there are radical social changes.) On the other hand, environmental quality (degradation due to increasing concentration of waste products), energy, or some other factor may prove limiting. Or people themselves may choose to limit population growth. Advocates of population control consider this necessary if people are to continue on this planet at something better than marginal survival levels.

Investigation 16-1
How can Clarion be improved?

Students make two kinds of decision in this Investigation. They have to decide what outcomes they

Figure 16-1T



should strive for. For example, they may want to increase the ratio of income to population or food to population. Or they may want to increase the environment index.

After the students set their goals, they have to decide how to invest money to achieve these goals. They must hypothesize what effects different projects will have on the indexes. The data from each round will provide feedback on their hypotheses.

Graphing the various indexes as the game is being played (for example, on overhead transparencies) will allow students to spot trends. Whether or not they are used on a projector, one graph can be laid on another, and relationships between indexes sought. Students might compare the graphs of food and population, or income and environment. The graphs in Figures 16-2T through 16-8T show the trends for budgets that remain constant all ten rounds. All projects within a color group have the same effect.

In designing *The Planet Management Game,* special efforts were made to build in some "chance" factors. For example, in conducting a research project to develop improved food-producing plants, there could be a huge increase in the food supply, but not necessarily. This characteristic of the game makes it parallel more closely the uncertainties of real-life situations.

The students should not be told about the built-in characteristics of the game. The excitement of possible discovery gives the game one of its principal appeals and its unique value as an educational experience. Some students may perceive that using only one project at a time provides better data about its effect.

Figure 16-2T *6 bux invested in red color group for 10 rounds*

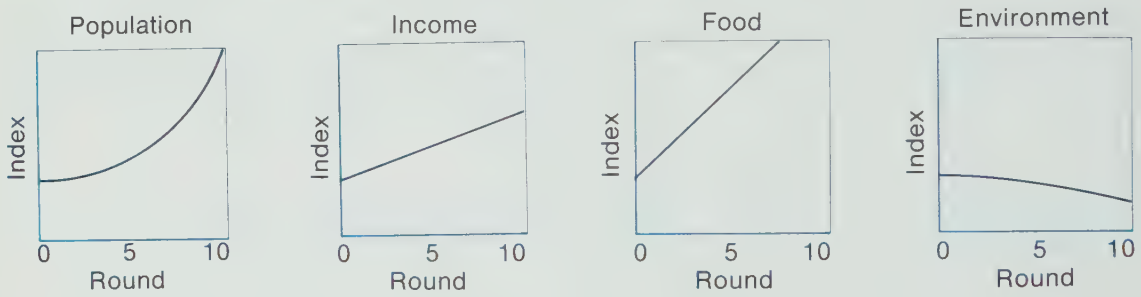


Figure 16-3T *6 bux invested in blue color group for 10 rounds*

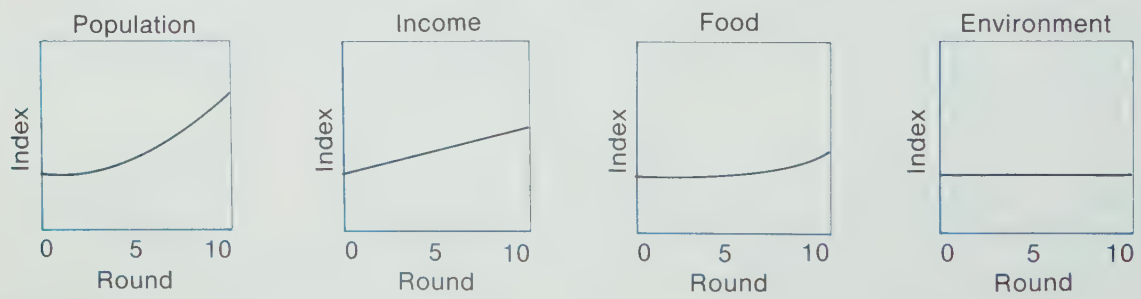


Figure 16-4T *6 bux invested in orange color group for 10 rounds*

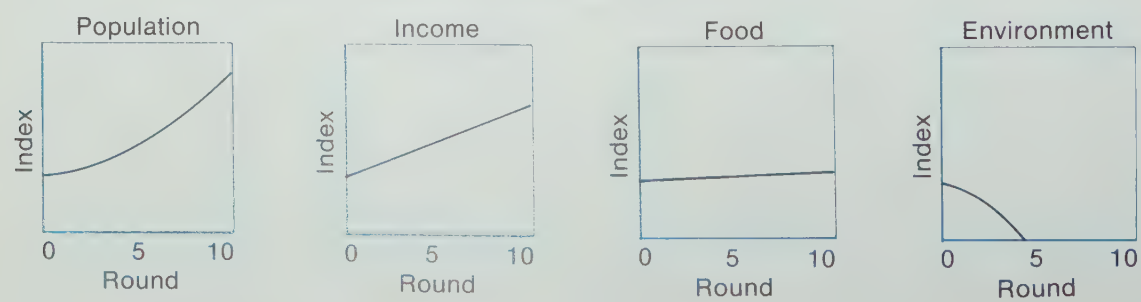


Figure 16-5T *6 bux invested in yellow color group for 10 rounds*

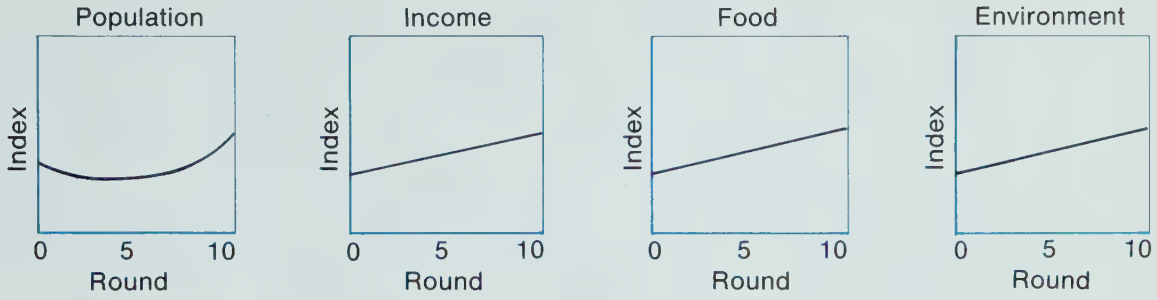


Figure 16-6T *6 bux invested in green color group for 10 rounds*

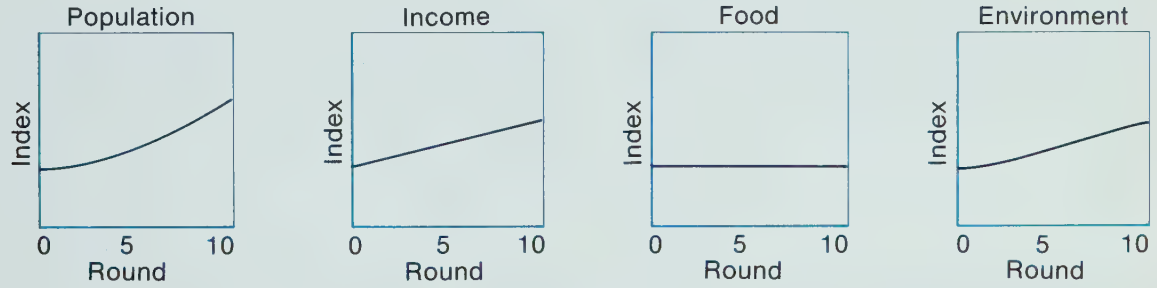


Figure 16-7T *2 bux invested in each color group for 10 rounds*

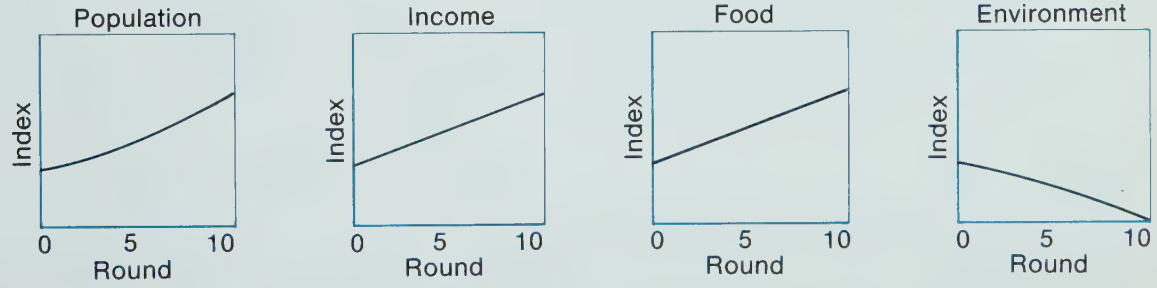
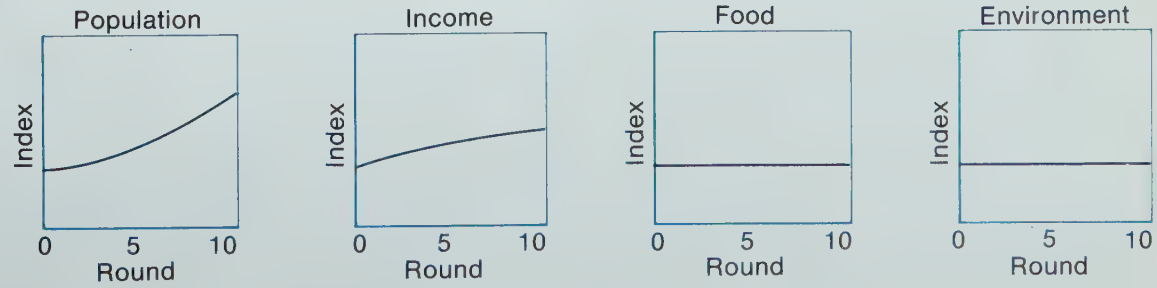


Figure 16-8T *no bux invested for the entire game*



If no one tries this approach you might suggest it to students as a data-gathering device before they play the game a second time.

Activity time: 5–6 class periods
The students can probably play 2 or 3 rounds in one class period. At least one period will be needed to choose a winner. (If the game is played a second time, allow 3 or 4 more days.)

Materials (groups of 5 or 6):
The Planet Management Game available from Houghton Mifflin Company. Contact your local sales representative or regional sales office. Each group will need a game.

Analyzing data
The students themselves should decide which group won the game. Make sure that the discussion includes the relative changes (ratios) of income and food compared to population. If arguments become so intense that they obscure the main point of the game, it will be wise to propose:

1. No winner be declared.
2. The game be played again.
3. The criteria for winning be established before the replay starts.

The indexes for an Earth-Management Game could be other indicators of resources such as energy, or data about life span, prevalance of disease or malnutrition, or amount of leisure time. Psychological factors might be considered, but would probably be difficult to quantify.

References

Ehrlich, Paul R. *The Population Bomb.* New York; Ballantine Books Inc., 1969. A classic on the dangers of overpopulation.

Scientific American, September 1974. This entire issue deals with human population.

17 People cause change

Behavioral Objectives

The students will learn
1. to analyze the effect of people on their environments.

They will show they have learned
1a. by inferring some of the consequences of changes people make in their environment. (Extend Your View 17-1)
1b. by identifying the kind of data needed to check these inferences. (Extend Your View 17-1)

Overview

In these Investigations, students analyze human interaction with the environment. Students practice breaking down large human-environmental interactions into smaller, more manageable parts. They develop an awareness of the reasons why people change their environment and the consequences of these changes. They identify the kind of data needed to better understand the interaction. In subsequent Investigations, students study more specific environmental problems.

In Investigation 17-1, students chart the steps in the production and use of a particular energy source. They identify how each step might affect the environment. In Investigation 17-2, students look at photographs of an environment before, during, and after a human intrusion. They identify or infer changes that have occurred, as well as reasons for the human intrusion. Since mainly visual data are supplied, students also identify the kinds of data they would need to better understand the situations.

Background

Strip mining and other forms of surface mining are on the increase because of the relatively low cost of extraction. Strip mining is used primarily for the extraction of coal. Strip mining is practiced heavily in Kentucky, Ohio, Pennsylvania, West Virginia, Illinois, Montana, and the Four Corners region of Arizona, New Mexico, Utah, and Colorado. Strip mining is also a

common practice in British Columbia, Saskatchewan, Australia, England, and Germany. Other potential areas may be developed as land becomes scarcer and more expensive, and strict laws are passed in areas presently being mined. Continued development of bigger shovels makes the reworking of old beds possible. Also, surface mining of coal 700 metres below the surface has been predicted in the near future.

Unfortunately, the socioeconomics of strip mining cannot be well-portrayed in a photographic essay. The effect of extensive stripping on nearby communities may be devastating. The refinement of mining technology has enabled more coal to be extracted by fewer workers. Farmers who lease their land or sell their mineral rights either leave the area permanently or are prevented from farming the area for many years. Existing antiquated laws often assign the lowest property value to reclaimed land. This may reduce revenue to the community. Extensive stripping often stops the influx of industry and professionals into nearby communities because the water supply, land values, access roads, and the economy of the area are uncertain.

The problems of reclamation are far more complex than those cited in the text. Geology is a key factor in the success of reclamation. The processes of nature that formed coal beds were also responsible for forming plenty of iron pyrite (FeS_2) in the same vicinity. This mineral is the source of the "acid mine drainage" associated with both deep and surface coal mines. Sulfuric acid (H_2SO_4) is produced when iron pyrite is exposed to air and water. Acid drainage in the spoil banks weathers other rocks, releasing such minerals as iron and manganese. These minerals often poison plants and animals and pollute streams and lakes. Surviving plants have the additional problems of the spoil-bank environment, with no soil and almost no water-holding capacity.

The most successful reclamation has occurred in areas where the geologic strata are rich in limestone. Basic limestone ($CaCO_3$) neutralizes much of the acid from the iron pyrite. Areas void of limestone are sometimes impossible to reclaim. Awareness of this problem has prompted research by both environmentalists and coal companies. New technologies, involving burial and sealing of the iron pyrite wastes to prevent weathering, have been somewhat successful.

Regulations regarding the quality of reclamation vary from area to area. Because reclamation efforts are expensive, companies usually comply with only the minimum legal requirements. The cost for reclamation is usually passed on to the consumer in the form of higher prices for coal and other products, such as steel and electricity. When states and localities pass stricter laws, higher-quality reclamation results.

Investigation 17-1
The effect of using energy

These are some possible answers to the question about the impact of using wood as an energy source.

1. The tree, by the process of photosynthesis, converts energy from the sun to chemical energy that is stored in the tree. The tree takes nutrients from the soil and provides shelter and shade for other organisms.
2. The man uses energy to cut down the tree and saw the wood into smaller pieces. The removal of trees increases the chance of soil erosion. (Roots help hold the soil and leaves break the impact of rain.)
3. The small branches may be used for kindling or may be left to decay and return their elements to the environment. Decaying material provides nourishment for microorganisms and some insects.
4. Heat energy evaporates moisture from the stack of logs. This moisture is released into the environment.
5. Muscle power is once again used to split the dry logs.
6. The woman uses energy to carry the logs to the fireplace.
7. The energy in the logs is converted to heat and light energy (and a little sound) in the fireplace. The smoke can be considered a pollutant to the environment.
8. Energy is used to sweep the ashes from the hearth. When the ashes are returned to the environment, the minerals are returned to the soil.

Some sources of energy that the class may choose to study:

1. electric power	from natural energy source to electric light bulb and appliances
2. food	from farm to human waste
3. gasoline	from prehistoric plants to automobile exhaust
4. cooking gas	from prehistoric plants to a gas stove
5. wind	from the sun and atmosphere to a source of energy for windmills or sailboats
6. coal	from prehistoric plants to homes or industries
7. solar energy	from sunlight to home heating
8. falling water	from water and gravity to electricity

After the energy source is selected, a starting point and an end point should be agreed upon. The steps

can be developed through class discussion and recorded on the chalkboard. The steps may be revised as the students proceed.

Activity time: 3–5 class periods

Analyzing data

1. Some important steps may have been left out. For example, students may be unaware that there are transformers between the electric power plant and their home. Help the students improve their diagrams.
2. The answer to this question depends on one's viewpoint and values. Cutting down a tree may save the foundation of a house but leave a family of birds homeless. Burning a log may add smoke to the air but provide necessary heat for a house.
3. The reasons for using an energy source may be numerous. A particular source may be used because it is more convenient, most economical, has the least affect on the environment, or is the only option. For example, a tree may have been planted for shade, lumber, fruit, esthetics, or fuel. It may have been cut down for fuel or because it was too close to a house. It was probably cut into small pieces to make it easier to handle and burn. It was probably dried to make it burn better. The wood may be burned for heating, cooking, or lighting. Or the wood may have been burned in an attempt to conserve a resource that was originally cut for other reasons.

   Most environmental changes help some people and "hurt" others, especially changes that affect large numbers of people. People in Los Angeles benefit from the electricity produced by the coal mined in the Four Corners region. But the people in the Four Corners region are left with a damaged environment.
4. There will probably be many gaps in the information students gather about their energy source. They may not know how the energy is produced or where it goes. Students may express a need for quantitative data or a need to understand why the energy source was used. This type of information will be covered in later Investigations. Point this out, if necessary, to prevent students from feeling as if they are "left hanging."

Investigation 17-2
Changing the earth's surface

This investigation is designed to make students aware of the many changes caused by strip mining. The photographs are not sufficient to understand all the changes. This gap is deliberate. Students must also identify what additional data they would need to more fully understand the problem.

Activity time: 2 class periods

Analyzing data

1. Some changes that might be observed from the photographs:
   a. Changes in the landscape. Often hills are leveled, high spoil banks are left, and topsoil may be totally eliminated, creating a "desert" landscape.
   b. Erosion. Gulleys may be visible.

   Some changes that might be inferred from the photographs:
   a. Pollution. There will be increased noise pollution from blasting and operation of equipment, and air pollution from the equipment used to mine the coal and from coal dust.
   b. Clogging of streams and lakes with excess sand and silt from runoff.
   c. The pollution of water with minerals from broken rock.
   d. Changes in the landscape. The land may be unstable, and may take years to settle. New lakes are often created.
   e. Fluctuations in populations. Forest animals cannot survive in the new habitat; field animals may still flourish if vegetation thrives. Because of harsh surface conditions, hardier species may flourish. New species of plants may be introduced to cover land; old species may not be hearty enough to survive.
   f. Energy use. The solar energy that could be trapped by photosynthesis is lost until plants begin to grow again. Energy is used to operate shovels and other equipment. The energy of coal becomes available and is moved out of the area.
2. Students should consider, for example, problems and benefits to nearby communities, to cities and factories purchasing the coal, to the coal mine companies, to nearby farmers, or to vacationers. Encourage students to be aware of the many different implications involved in environmental problems.
3. Students should identify both specific questions they would want answered, and sources they would use to find information such as books, magazines, newspapers, television specials, letters to coal companies, local agencies, and local residents. Many of the questions raised will be studied in later Investigations.

References

Branson, Branley Allen, "Stripping the Appalachians." *Natural History,* November 1974. Discusses the extent and consequences of strip mining in the Appalachians.

Hirst, Eric, "Living off the Fuels of the Land." *Natural History,* December 1973. Discusses the use of energy in the production of food.

Woodwell, George M., "Short-circuiting the Cheap Power Fantasy." *Natural History,* October 1974. Traces back the energy used to support technology to biotic resources.

18 What changes your environment?

Behavioral Objectives

The students will learn

1. to recognize changes in their environment.
2. about the concepts of energy flow and pollution.

They will show they have learned

1. by identifying changes in their environment. (Extend Your View 18-1)

2a. by identifying examples of energy flow and pollution in their environment. (Extend Your View 18-2)

2b. by explaining how the interruption of one form of energy flow affects the environment. (Extend Your View 18-3)

Overview

These Investigations are designed to make students aware of changes in their environment. In Investigation 18-1, they identify such changes. In Investigation 18-2, they examine their home as a system that interacts with the environment. Using a simple tool (the input and output lists), they can evaluate the effects of this system. In Investigation 18-3, they investigate at least one example of the interruption of energy flow in their immediate environment.

The Investigations in Unit Four focus on various aspects of people's interactions with their environments. This first set of Investigations uses the students' immediate environment to develop the concepts of change, pollution, and energy flow. These concepts are operationally defined by the students.

Investigation 18-1
Finding changes in your environment

Students may have a better perception of what they have learned if their findings are organized in some fashion such as a bulletin board, a play, or a slide-tape show. You may also wish to have students record the questions that come from their discussions. These questions can be discussed throughout this unit. If the students wish to formulate certain concepts formally (for example, pollution), the definitions can be tested in each of the subsequent Investigations.

Activity time: 1 class period
Identifying the changes can be a homework assignment.

Analyzing data

1. If students focus on their immediate environment, they may identify changes that make their lives easier as improvements. If students take a broader view of the "environment," they may identify changes that best fit natural cycles as improvements.
2. Aim for a more general definition of pollution, rather than identifying specific examples such as accumulating garbage, or dumping wastes into rivers and lakes. For example, pollution might be defined as matter that has been removed from its normal environment. Students may limit the definition to matter that is where people do not want it to be. If students use the term "natural" in their definition, then that term should be defined.
3. Things that make people's lives easier are usually things that use more energy. For example, most

new, work-saving products—electric toothbrushes, electric fry pans, drills—need electricity to run. Convenience items like paper plates, plastic cups, and utensils seldom are reused, and cannot easily be recycled with our present technology. Even glass soda pop bottles that could be recycled are produced as nonreturnable for the convenience of the consumer.

Investigation 18-2
How does your home affect the environment?

The listing of input and output items may tend to get quite complex. However, if students consider each input item and then discuss the possible output items that it may produce, this should keep things relatively ordered. Some of the items that may be used are:

Input	*Output*
water	sewage
natural gas	water
electricity	noise
food	garbage
people	air
dirt	dirt
sunlight	odors
wood	heat
sound	light
air	discarded clothes
odors	
pets	
furniture	
clothes	

Activity time: 1–2 class periods

Analyzing data

1. Figure 18-1T is an example of an input-output list. Energy could be saved by taking shorter or cooler showers to save the gas or electricity that heats the water. Cooking in larger batches and eating more leftovers will also save energy. Keeping the shades up on windows during the day could help heat a home in winter and save on electricity for lights. Insulating homes helps to reduce heat loss.
2. The output list will generally contain the greater number of **P**-items. There are a number of ways to reduce the amount of **P**-items. Wiser shopping could cut down on the amount of food that is wasted. Buying fewer packaged foods and beverages in nonreturnable bottles would reduce the accumulation of garbage. Many communities are prohibiting the use of home incinerators because of the air pollution they produce.

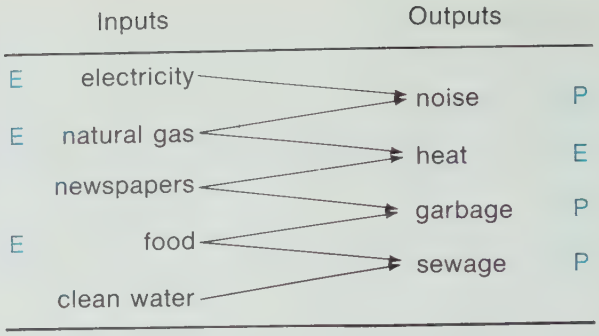


Figure 18-1T

3. Using any item that would normally be thrown out is a form of recycling. This could mean using newspapers for wrapping gifts or empty plastic containers for storage. Self-contained, home sewage-treatment systems are now being sold. These systems use the same water over and over. The sewage from these systems is collected at intervals and used as land fill instead of flowing into sewage drains and possibly into rivers and lakes.
4. The focus here should be that each home, whatever size, does affect the environment. The effect of each individual home may be small, but when multiplied by the total number of homes, the effect can be great. Industries sometimes try to avoid their responsibility by arguing that each individual company does not personally cause much pollution. But the effects of many industries can be significant. To combat pollution and energy waste takes the effort of many individuals.

Investigation 18-3
What happens when energy flow is interrupted?

The success of this Investigation depends on a number of factors. The students should be allowed to freely discuss and choose the situation they are going to study. Make sure that the situation they choose is one that clearly demonstrates an energy interruption. You can do this by asking questions such as: "Is there an actual energy flow present (change in input versus output)? Does your example involve energy sources directly or indirectly?"

You might use this example to show the complexity of an energy interruption. What if teachers go on strike? Would you call that an interruption in the flow of energy in a community? What if, because of the strike, schools had to be closed? And because schools closed, the school buses did not run? The bus drivers and maintenance men might be laid off. Because all

of these people are out of work, they might use their cars less. If it were winter, no fuel oil would be needed for the school furnaces.

Once the students begin to investigate their own situations, more questions will occur to them, which will help in organizing and developing their problem. Your role during this Investigation should be one of primary motivator and resource guide. You can help students get started by giving some thought-provoking examples. Probably every student has encountered the situation in which their home electricity went out for a while causing confusion as one person searched for a flashlight, another for matches or candles, and another checked the fuses. Maybe a student had been trapped in an elevator, on an amusement ride, or in a subway during a power failure. You might also discuss energy flow in more confined systems such as a space capsule or station.

Activity time: 2–3 class periods

Analyzing data

Students should conclude that almost any situation will affect some energy flow. They may also realize that the effects of an interruption in energy flow cascade; one effect causes a number of other related effects, which in turn cause many more effects.

19 Why is clean air important?

Behavioral Objectives

The students will learn

1. how to gather evidence of local air pollution.
2. that the amount of pollution inhaled depends on both the quality and the quantity of air one breathes.
3. that air pollution can damage and destroy plants.
4. that air pollution can harm people.

They will show they have learned

1. by describing some methods for studying air pollution in a community. (Extend Your View 19-1)
2. by identifying the variables that affect how much air pollution people breathe. (Extend Your View 19-2)
3. by using an experiment to show the effects of air pollution on plants. (Extend Your View 19-3)
4. by inferring, from data, some effects of air pollution on people. (Extend Your View 19-4)

Overview

In Investigations 19-1 and 19-2, the students sample pollutants in their community. In Investigation 19-1, students measure the *p*H of rainwater, which indicates the level of sulfur dioxide and nitrogen dioxide present. In Investigation 19-2, students collect data on particulates in the air. While data is coming in, they do Investigations 19-3, 19-4, and 19-5.

In Investigation 19-3, students calculate the approximate volume of air a person breathes daily and the amount of pollution it contains. They also test how physiological factors affect the amount of air inhaled.

In Investigation 19-4, the students see how one common air pollutant, sulfur dioxide, affects the health of plants. In Investigation 19-5, the students read about the human respiratory system and how it responds to air pollution. They then use public health records to test a hypothesis relating air pollution to the incidence of respiratory diseases.

Background

Air pollution is mainly a problem of the cities, although it often spreads into the countryside. It comes from the combustion of fuels, the evaporation of solvents, the burning of solid wastes, and mechanical and chemical industrial processes. Although southern California pioneered in the "pollution explosion," urban air pollution has become an international problem that has been growing steadily worse in the last 25 years. This poisoned air creates and aggravates respiratory diseases. It also reduces visibility and creates hazards for drivers and pilots. It damages forests and crops, injures livestock, corrodes metal, deteriorates masonry, may reduce property values because of damage, and costs the community large cleaning bills for everything from dusty draperies to smoke-blackened buildings. Table 19-1T shows the major sources of air pollution. (If you add up the columns the sums will not match the totals given. This is because the data have been rounded off.)

Table 19-1T *Sources of air pollutants in the United States (millions of tonnes per year)*

Source	*Carbon monoxide*	*Sulfur oxides*	*Hydro-carbons*	*Nitrogen oxides*	*Particles*	*Other*	*Total*
Transportation	60	1	11	6	1	1	78
Industry	2	8	4	2	6	2	23
Making electricity	1	11	1	3	3	1	18
Heating	2	3	1	1	1	1	8
Refuse disposal	1	1	1	1	1	1	4
Total	66	23	17	11	11	4	129

About 12 times more gaseous pollutants than particles enter the air. The combined effects of particles and gases are sometimes more serious than their separate effects. For example, sulfur dioxide, which is an irritant to living tissue, often becomes absorbed on the surface of particles in smoke. In this way it tends to penetrate deeper into the lungs, stay there longer, and do more damage.

Acute local accumulations of pollutants are usually avoided because prevailing winds tend to scatter pollutants as they are produced. When there is no wind or during temperature inversions, pollutants build up. In a temperature inversion, warm air slides over cooler, denser air. This keeps the pollutants in the cool air from rising and dispersing. After a few days under a temperature inversion, lethal conditions may be created. These inversions happen most often in valleys or in cities where the tall buildings keep the prevailing winds from circulating the air.

Temperature inversions caused the air pollution episodes of Donora, Pennsylvania, and London, England. Meteorologists predict that these crises will occur with increasing frequency. In response to the crisis in London, a Clean Air Act was passed by Parliament on July 5, 1956. Since then coal smoke, one of London's major pollutants, has decreased 50 percent. However, new energy sources and increasing energy demands have increased other pollutants such as sulfur dioxide and nitrogen dioxide.

Usually, the problems of dealing with air pollution are political as well as economic and technical. The United States is divided into many small jurisdictions, but polluted air masses do not recognize political boundaries. For example, the prevailing winds blow contaminants from New Jersey oil refineries, factories, and smoldering garbage dumps directly over New York.

In response to this national problem and episodes like Donora, the Environmental Protection Agency was formed under the United States Clean Air Act of 1970. The EPA is a federal agency whose major responsibility is to protect and enhance the nation's resources. Each state is required to submit to the EPA plans for implementation, maintenance, and enforcement of the national air quality standards. The states have complied by setting up air quality monitoring stations. The EPA is responsible for surveillance of the state implementation plans.

Investigation 19-1
Acid rain in your community

Activity time: 1 class period

Materials (groups of 2):

1 community map
28 sampling jars with lids (any type will do)
14 test tubes or vials about 10 × 75 mm (size is not critical)
14 solid rubber stoppers to fit test tubes or vials
14 waterproof markers or crayons
28 strips of *p*H paper, 4.5 cm
4 comparator color charts

Preparation

Community maps may be obtained from local government offices. Use short, wide sampling jars that will not be easily knocked over.

The most accurate *p*H paper to use is Micro Essential Laboratory's Lo Ion *p*H paper, with a range of 3.0–6.0. Test Kits containing 1 roll of *p*H paper, 1 color chart and 1 test vial (Cat. No. L1-5100) may be obtained from:

Micro Essential Laboratory
4224 Avenue H
Brooklyn, New York 11210

Individual *p*H paper refills and color charts may also be obtained.

Analyzing data

1. The *p*H readings will generally be lower near industrial areas or highways where exhaust fumes can accumulate.

2. Readings may vary because of atmospheric conditions. For example, during electrical storms some nitric acid is produced and can dissolve in the rainwater, making it more acid. Winds may carry gases to different parts of the community.

Investigation 19-2
Airborne particles

Activity time: approximately one week
Planning and preparation: 40 minutes
Checking slides: 30 minutes

Materials (individual):
1 community map
60 microscope slides
petroleum jelly
7 microscopes
60 spring-type clothespins
14 marking pens

Analyzing data
1. Students will most likely find more particles on weekdays since there is usually more industrial activity then.
2. Areas where there is combustion or unprotected ground are more likely to have high levels of particulate matter.
3. Rain washes particles from the air. If it rains just before the students set up their slides, fewer particles will be collected.
4. Black particles may be carbon or dirt blown up from the ground. Particles that have color may be pollen.

Investigation 19-3
How much dirt do you inhale?

Table 19-2 follows the standard practice of reporting the geometric mean for suspended particles and the arithmetic mean for sulfur dioxide.

Activity time: 2 class periods

Materials (groups of 2):
4 100-ml graduated cylinders
gallon jars or 2-litre beakers
plastic or rubber tubing with at least 6 mm inside diameter and 40 cm length
shallow pans or containers large enough for the jars to sit in
clock or watches with a second hand

Analyzing data
Some variables that might affect a person's breathing rate are exercise, basal metabolism rate, size of individual, sleep, or a disease like asthma or hay fever.

Investigation 19-4
How does sulfur dioxide affect plants?

Activity time: 1 class period to set up. During the next three days, the students observe changes in the plants while collecting data from the other Investigations.

Materials (groups of 2):
28 potted plants
10-ml plastic syringe or 10-ml pipette
100 g sodium sulfite
100 ml of 5 percent solution of sulfuric acid
28 clear plastic bags to cover plants
transparent tape, masking tape, or wire ties
2 balances

Preparation
Students can grow their own plants from seed. The seeds of rapid-growing plants such as green beans or peas should be planted two to three weeks before the Investigation. Seeds could be planted on different days, so that plants of different ages are available. Also, plants from previous experiments can be used, though their ages may be unknown. Several different types of plants should be investigated, for example, cabbage (waxy leaves), onion (thin leaves), tomato (hairy leaves).

For each experimental plant, 2 g of sodium sulfite and 2 ml of 5 percent sulfuric acid is recommended. Prepare the sulfuric acid solution yourself. Make up a 5 percent solution of sulfuric acid by pouring 10 ml of concentrated sulfuric acid into 90 ml of tap water to make 100 ml of the solution. Be sure to pour the acid into the water to prevent splashing and overheating. Students can measure out the 2 g of sodium sulfite, but you should add the sulfuric acid.

Analyzing data
The data should show that most of the test plants are sensitive to sulfur dioxide. Differences in reactions between species are due to physiological and anatomical differences, such as respiration rate, plant size, or leaf area. Some students might wish to further investigate these variables on their own.

Plants with thick, waxy leaves are usually more resistant to sulfur dioxide. Younger plants seem more quickly affected than older plants because of the fragile, newly formed cuticle (skin) with its high rate of metabolism.

Point out that there is no escape from gaseous pollutants. Even air conditioners do not filter them out. You might ask questions about the effects of such gases on crops, lawns, pets, and livestock.

Investigation 19-5
Can air pollution harm people?

Activity time: 1 class period

Analyzing data

The graphs indicate that the people who live in areas with the most polluted air are more likely to develop respiratory problems.

The students might like to know more about weather conditions that might aggravate pollution, or the working conditions of the people in the sample. Perhaps more men have problems because they work in factories. Students might also question the economic class of the participants. Maybe because of inadequate nutrition, poorer people are more susceptible to disease.

References

Wise, William. *Killer Smog.* New York: Ballantine Books, Inc., 1968. Documentary novel about the events and results of the air pollution episode in London on December 5, 1952.

20 How is Lake Erie changing?

Behavioral Objectives

The students will learn

1. to deal scientifically with large amounts of data.
2. that several measurable factors are useful indicators of eutrophication, the aging process of a lake.
3. that compounds that provide food for algae are a major cause of water pollution.

They will show they have learned

1. by finding patterns within a data bank. (Extend Your View 20-1)
2. by deciding what variables might contribute to the aging of a lake. (Extend Your View 20-2)
3. by evaluating plans for reducing the pollution in a lake. (Extend Your View 20-3)

Overview

There are two structured activities in this Investigation and an optional third activity, which is not mentioned in the student text. Investigation 20-1 challenges each student to find part of the answer to the question, "What is happening to Lake Erie?" The students search through a "data bank" for relevant information. Then the class discusses the patterns that each person found in the data.

In Investigation 20-2, the concept of eutrophication is presented and the class turns again to the data bank to find how pollution affects the aging of Lake Erie. In the class discussion, students consider how pollution of Lake Erie could be stopped.

An optional Investigation involves the study of a local river, lake, or harbor. The class would need to make its own data bank, using information from a local library or a water pollution control agency. Students can supplement this information by analyzing samples from local waters, and by evaluating the effects of various brands of detergents or other pollutants such as fertilizers.

Background

Two types of water pollution can be distinguished: contaminating and fertilizing. Contaminated water contains toxic chemicals, bacteria, or other microorganisms that can directly kill other organisms. Parts of Lake Erie are heavily contaminated. Fertilizing pollution refers to the addition of chemicals and substances, such as organic matter, that increase the productivity of a body of water and speed up the process of eutrophication.

Eutrophication is a natural process occuring in all ponds and lakes. The word "eutrophic" is derived from a Greek word meaning well-nourished. Lake Erie is in an advanced stage of eutrophication. That is, the lake has a relatively high concentration of mineral and organic compounds in solution, which promote rapid and extensive growth of algae.

The eutrophic state is actually the high end of a scale on which all lakes may be classified according to their "primary productivity." Primary productivity is the rate at which photosynthesis occurs and produces plant matter that can then enter food chains.

Lake Erie at one time had a very low primary productivity. The water was clear, and the populations of plants and animals in the lake were small. Lake Superior is still like that. The other Great Lakes have primary productivities ranging somewhere in between Lake Erie and Lake Superior.

Present ecological theory holds that the natural evolution of *all* lakes is from low productivity (oligotrophic) to high productivity (eutrophic). People's pollution of lakes has accelerated this change. Eventually all lakes acquire high levels of nutrients, increased plant life, and changing animal life. A lake slowly fills up with organic matter and sediment until it becomes a swamp and, ultimately, dry land.

The popularly-held view that Lake Erie is dead is literally not true. The lake is changing. People have hastened its natural evolution from a relatively clear, deep lake to a more eutrophic state. Lake Erie is actually living much too rapidly. There are many ways to describe the nature and symptoms of the pollution of Lake Erie. In these Investigations, your students will find their own ways.

Investigation 20-1
What is happening to Lake Erie?

Many data-bank entries in this Investigation came directly from reports of the Federal Water Pollution Control Administration. The entries have been edited only enough to assure that an average student can detect the patterns. Entries vary in difficulty. All the data is valid, but varies in the degree of relevancy to this Investigation.

Activity time: 2–3 class periods
One class period plus an overnight assignment should give each student enough time to interpret the data or find a pattern. Allow at least one class period for presenting findings and reaching conclusions.

If nearly all students have worked on the same entries, another day could be used to survey the remaining data. If this happens, it might be interesting to discuss why some data entries were preferred. It is not necessary that all the entries be analyzed, just that each student consider at least two sets of data.

Materials (individual):
28 sheets of graph paper (optional)

Preparation
If you want to supplement the data bank with additional information, organize the different entries into folders and number them starting with "Entry 14."

The data in these entries is as recent as possible. However, Lake Erie continues to change and each year new data may be available.

Analyzing data
These are some of the major patterns that can be observed and inferred from the data bank.

Entry 1 The Lake Erie drainage basin includes more large cities than the drainage basins of the other Great Lakes.

Entry 2 The western section could probably become polluted the fastest because of its shallowness. But it could also be cleaned the fastest because its flushing period (the time it takes a volume of water to be completely replaced by new water) is the shortest.

Entry 3 Students could infer that the cisco and whitefish have died out because the lake has changed and become more favorable for perch and carp. This is what has generally happened in Lake Erie. Students could substantiate this inference by researching the needs of these different fish. The changes may be part of a natural cycle, although this is not likely.

Entry 4 The number of algae has increased from 1927 to 1962. The year 1973 shows a slight decrease. This entry correlates nicely with the total phosphorus graph in Entry 13.

Entry 5 Dissolved oxygen measurements are a critical indicator of the state of a lake or pond. Aerobic decay is much faster and much more efficient than anaerobic decay. Aerobic decay would be the major form of decomposition until the oxygen is used up.

At certain samplings, the COD exceeded the average available oxygen (20 mg/litre). This is deadly for the organisms in these areas. The data for the three sections confirm the speculation from Entry 2 that the western section could become the most polluted.

Entry 5B shows a trend toward higher oxygen depletion each year. In 1969 the dissolved oxygen in the bottom waters was depleted in August, well before the autumnal overturn. This is a highly eutrophic condition for the lake.

Entry 6 This entry shows a trend of increased use of Lake Erie's water. The difference between the volume of water used by industry and by homes should be noted.

Entry 7 A correlation can be made between large population centers and high concentrations of coliform bacteria. Especially high concentrations can be noted for the western section and the Detroit area.

Entry 8 This entry should indicate that one of the major sources of pollution for Lake Erie is the Detroit River that carries sewage from Michigan. Construction of adequate sewage-treatment plants for all major population centers along Lake Erie has begun.

Entry 9 This entry shows a general trend of increasing numbers of bottom-dwelling organisms that do not require a high oxygen content, and decreasing numbers of those that do. But the erratic fluctuations between 1929 and 1930 should lead the perceptive student to question if the "trends" are just normal fluctuations. The difference between 1929 and 1958 is highly significant.

Entry 10 Wind direction probably has little to do with lake aging, but the circle of wind in the western section probably does not help the stagnation of that already-polluted section.

Entry 11 Students should note the high amounts of phosphorus and nitrogen in sewage. More important, there is a strong relation between the amount of phosphorus and algae growth.

Entry 12 Entry 12A shows a trend of increasing amounts of phosphorus in detergents. Entry 12B shows the wide range of phosphorus in detergent brands in 1970. Assuming the 1974 levels in the Cleveland area are similar to those in other Lake Erie communities, the general decrease in detergent-phosphorus levels correlates nicely with Entry 4 and Entry 13A.

Entry 13 The increased use of detergents has significantly increased the phosphorus-loading of Lake Erie. It can be inferred that the drop in phosphorus-loading in 1972 was due to a drop in the use of high-phosphate detergents, since the population has continued to grow. This entry correlates nicely with Entry 4. Unfortunately, no information could be obtained on industrial or other sources of phosphorus.

Investigation 20-2
How old is Lake Erie?

The students should be able to relate the patterns of change they found in Investigation 20-1 to the natural processes that occur as a lake ages. Discuss the drawings in terms of increasing primary productivity and increasing age.

Activity time: 2 class periods
Using the data bank: 1 class period
Discussion: 1 class period

Analyzing data

1. Lake Erie would probably be younger because pollution, especially fertilizing pollution, contributes to the aging of a lake.
2. Fertilizing pollution.
3. Aging would continue, but at a slower rate.
4. They could reduce their use of detergents and fertilizers high in phosphorus and nitrogen. They could also demand and support adequate sewage-treatment facilities.

Investigation 20-3 (optional)

After Investigation 20-2, the class can apply the knowledge gained from Lake Erie to a local problem. Students can gather data by using the library, listening to speakers, and writing or visiting local regulatory agencies.

This activity can be expanded by conducting analyses of water from local lakes and streams. Analysis of detergents is also worthwhile since they have been specific polluting agents.

Activity time: 5–10 class periods

Materials (class):

A collection of data on a pollution problem in a nearby river, lake, or harbor

Preparation

Methods of water analysis are described in *Standard Methods for Examination of Water and Wastewater.* Students can measure acidity, phosphate content, or nitrate content. The tests require some advance preparation and some specialized chemicals, but these can be found in most high school chemistry laboratories. Kits for testing water are available from

LaMotte Chemical Products
Chestertown, Maryland 21620

or other major suppliers of scientific materials.

Extend Your View 20-1
Which lake is more polluted?

Some students may say that the larger fish catch in Lake Erie indicates that the lake is less polluted. People often assume that pollution always causes an immediate drop in productivity. Fish are high in the food chain and live in environments where the primary and secondary productivity is abundant enough to provide food. A nutrient-rich lake like Lake Erie will support an abundant fish population until either the lake ages to an anaerobic state or contamination kills the fish.

Extend Your View 20-2
Is Crystal Lake dying?

Most of the answers are based on data from the study of Lake Erie. Some of the answers are debatable and may vary with local conditions.

1. N. The thickness of the ice is related to only the climate.
2. M. Sulfur *may* be a pollutant, especially in certain local-industrial situations, but students were never given any information about it.
3. Y. Dissolved oxygen is a key indicator of pollution and eutrophication.
4. M. Students might argue that water skiers are indicators of pollution from boats and from people. Depending upon the size of the lake, this may or may not be significant.
5. N. The size of one fish is not an indicator.
6. Y or M. Students might ask for data on the amount of untreated sewage.
7. N. Week to week variations of algae populations are usually not significant in studying pollution effects. Changes over at least a year are necessary.
8. Y. The kinds and numbers of fish are an indicator of the state of the water.
9. M. There are always bacteria in lakes. Students might ask for information on numbers and kinds.
10. Y. Phosphate level is a good indicator of pollution.
11. N. The direction of winds will not vary with the degree of eutrophication.
12. Y. The amount of algae over a 10-year period is a very good indicator of changes in the lake.
13. M. Students may reason that sport fishermen (like water skiers in Statement 4) can add to pollution.
14. Y. Bottom-dwelling organisms are good indicators of the conditions in a body of water.
15. M. Depending upon the size of the lake, the size of motorboats may be a significant pollution indicator (oil, gas, and bottom disruption).
16. Y. The concentration of coliform bacteria is a good indicator of pollution.
17. M. Some plants are indicators of pollution. More information is needed.
18. N. The presence or absence of snakes along the lake shore is probably not an indicator.
19. Y. A green scum on the lake probably indicates large algae blooms.
20. M. The status of property values may not be significant. However, some students may argue that a polluted and smelly lake would deter buyers and reduce property values.

References

Dasmann, Raymond F. *Environmental Conservation.* New York: John Wiley and Sons, Inc., 1972, pp. 326–329. Discussion of eutrophication.

Odum, E. P. *Fundamentals of Ecology.* Philadelphia: W. B. Saunders, 1959, pp. 308–314. Another discussion of eutrophication.

Standard Methods for Examination of Water and Wastewater. New York: American Public Health Association, 1965. Technical reference on all aspects of water-testing.

The Tahoe Research Group, "Tahoe's Troubled Waters," *Natural History,* January 1975. Discusses the possible effects of large-scale urbanization on the Tahoe ecosystem.

Recent publications of:

Federal Water Pollution Control Administration. U.S. Department of the Interior, Washington, D.C.

Great Lakes Fishery Commission. Natural Resources Building, University of Michigan, Ann Arbor, Michigan.

International Joint Commission, Ottawa, Quebec, Canada

Recent issues of: *Catalyst for Environmental Quality, Environment,* and *Limnos.*

21 Have our energy needs changed?

Behavioral Objectives

The students will learn

1. some of the variables that change our energy needs.
2. that many points of view contribute to decisions concerning energy sources.

They will show they have learned

1. by explaining how energy use is related to the size and lifestyle of a population. (Extend Your View 21-1)
2. by discussing some of the variables that influence a decision about a new energy source. (Extend Your View 21-2)

Overview

These two Investigations are designed to help the students understand how energy use affects their environment. In Investigation 21-1, students examine data to answer the question "How much energy do we use?" The data leads students to consider the historical aspect of energy use. This Investigation can be expanded to utilize community resources such as libraries, guest speakers, or information services of local industries.

In Investigation 21-2, students play roles in a hearing to decide whether or not to allow the construction of a nuclear power plant as a new source of electricity. Students also consider ways to prevent or reduce thermal pollution. This Investigation gives students a chance to identify some of their own attitudes about pollution. They should be able to see how their lifestyle can affect ecosystems.

Background

The impact of energy use on the environment has only recently been recognized in our society. In their attempt to control the environment, people use increasing quantities of energy. The use of air conditioners in summer, heaters in winter, and lights to extend the daylight hours are just a few examples. The production of a large number of manufactured goods also results in increased energy use. The environmental impact of air, water, and solid-waste pollution has been apparent for some time. Thermal pollution, the seemingly inevitable by-product of energy use, is a more recent concern.

People are now faced with some basic environmental problems. The continually-increasing demand for energy has forced people to consider the interaction of people and the environment. What effect does energy use have on the environment? Pollution in all its forms must be considered. Also basic scientific-technological problems, such as the development of new energy sources, are dependent on value-based decisions. What do people want out of life? How many "conveniences" do they need? What is the price they must pay for energy use?

Investigation 21-1
How much energy do we use?

You might want to ask a student or teacher with a background or interest in world history to tell the class about events during the 18-year period under discussion.

Discussions should help students focus on their own lifestyles—what forms of energy they need and how badly they need them. Point out the relation between lifestyle, consumer decisions, and the level of technology.

Activity time: 1–2 class periods

Analyzing data

Students will probably immediately attribute increases in energy use to increased population. Try to get students thinking about other factors. For example, Africa uses comparatively little energy. The newly-developing African nations have not yet reached the state of industrialization found in Europe, Japan, and North America.

One might infer that the increase in energy consumption for the United States is a function of lifestyle. People may have become accustomed to using energy to make their lives easier. For the period shown, western Europe or Japan show much greater increases in consumption than the United States. In both these cases World War II may have kept industrialization rates low. After the war, reconstruction would have forced the energy consumption rate to increase.

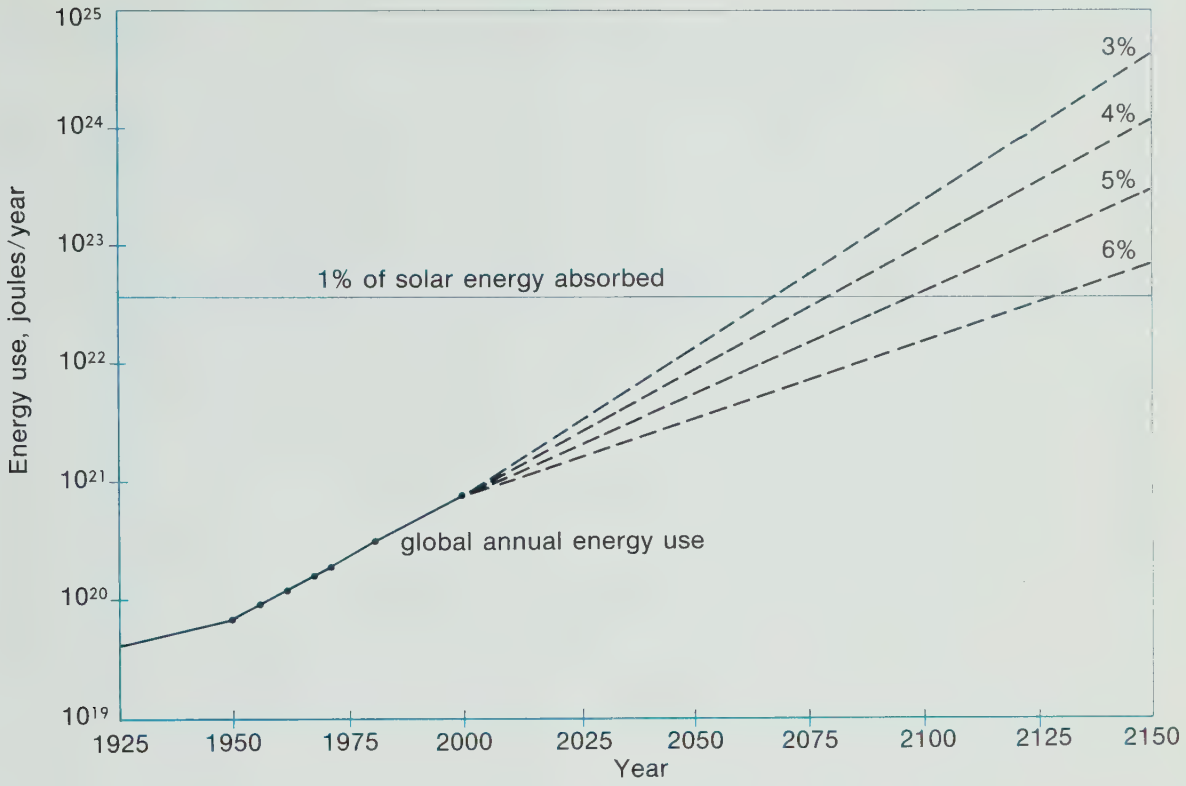


Figure 21-T *Reprinted from "Energy and the Weather," by James T. Peterson.* Environment, *Vol. 15, No. 8, p. 9. Copyright © Scientists' Institute for Public Information, 1973.*

1. High energy use per capita indicates an industrialized region. High overall energy consumption also depends on the size of the population of a region. Low energy use per capita indicates non-industrialized regions.
2. The graph in Figure 21-1T shows the world energy use for the year 2000 as 10^{21} joules per year. The assumption made here is that the world population and the demand for energy will increase at their present rates. The dashed lines after the year 2000 are predictions based on different annual energy growth rates.

   Students could make different assumptions about population and industrialization in the year 2000. However, their energy-use prediction should still show energy use related to population and industrialization. You may need to tell the students that they can start their graphs at 1925 or 1950 and at an energy use other than zero.

Investigation 21-2
The nuclear power plant controversy

This Investigation is purposely simplified. One aspect of the controversy about nuclear power plants is the potential health hazards of radioactive materials released into the environment. This aspect was omitted because junior-high students usually do not know enough about radiation to be able to interpret the available data. If you wish to discuss this aspect of the problem, use the references on page T86.

Players are, in effect, choosing among alternatives like these:

1. An expensive but efficient water cooling system, over low costs for electricity and consumer goods.
2. A pleasant lake for fishing, swimming, and boating (which they may not even use), over a higher return on investments.
3. A reduction (or at least no increase) in the amount of electricity available, over the convenience of many electrical appliances.

You should be able to infer from their statements a willingness or lack of willingness to choose such alternatives.

Activity time: 2–4 class periods

Strategies should be planned during class time. Devising the strategies will take at least one class period. The time required for a postgame discussion will be

determined by the amount of enthusiasm generated during play. One class period may be sufficient. If the hearing and class end at the same time, the SSC members may be able to get together and reach a decision before the class meets again.

Materials (class):
any data to supplement the data bank

Analyzing data
Begin with simple, concrete questions that focus on what students did. Then ask questions that require more analysis of the positions and actions taken.

1. Which group(s) won the SSC's decision? What did the group(s) do to gain the Commission's support?
2. Did the other groups seem to do anything to cause the Commission to vote against them?
3. What penalties or threats did the opposing sides use to try to get their own way?
4. What problems did the SSC have in trying to be fair?
5. Why would a power company, industrial association, and majority of the city council be on the same side? Why would a Citizen's Committee, Friends of the Environment, and a minority of the City Council take the same position?
6. Why should the SSC be given the authority to decide the issue? Why not the groups involved?
7. Was the hearing fair? Do you think you could have done better if you had played "yourself" instead of an assigned role?
8. Which position would you have supported if you owned stock in Wattson Electric Company but lived in another area?

References

Nelkin, Dorothy, "The Role of Experts in a Nuclear Siting Controversy." *Bulletin of the Atomic Scientists,* November 1974. A case study of a nuclear power plant proposed in 1973 for Cayuga Lake. The roles of citizens, scientists, and the New York State Electricity and Gas Company are discussed.

"Nuclear Power: How Great is the Risk?" *Science Year, The World Book Science Annual.* Chicago: Field Enterprises Educational Corporation, 1975.

Shore, Ferdinand J., "Commercial Nuclear Steam—Electric Power Plants." *The Physics Teacher,* September and October 1974. Part I discusses principles of operation and some aspects of safety. Part II sketches several important points about the nuclear energy controversy.

Woodson, Riley D., "Cooling Towers." *Scientific American,* May 1971. Describes how different types of cooling towers work.

Various materials are available free on request from:
United States Atomic Energy Commission
Oak Ridge, Tennessee 37830

Films

Energy: The Nuclear Alternative. A Churchill Film, Los Angeles, California. Color. 20 minutes. Presents the views of citizens, scientists, the utilities, and the Atomic Energy Commission on the nuclear power controversy.

22 The Redwood Controversy®

Behavioral Objectives

The students will learn
1. that land-use problems have conflicting ecological, social, political, and economic components.

They will show they have learned
1. by explaining why an environmental issue may be difficult to resolve. (Extend Your View 22-1)

Overview

The purpose of *The Redwood Controversy®* is to help the students understand the issues involved in environmental planning. It is not enough merely to understand scientific principles. To effectively use their knowledge of science, people need to know how decision-making processes work and how to influence them. In this Investigation, students get involved in a decision-making process. They play the roles of Senators and Senate witnesses in a simulation of the events that preceded the vote on the Redwood National Park.

Background

The Redwood Controversy® is designed to give students insights into the political and sociological issues that make it difficult to resolve ecological problems. Issues such as the authority of the federal government to take private lands should be resolved on their own merits—no easy task. But these issues seldom are. More often, tangential problems, political obligations, and personal interests are more influential in shaping the final decision than the facts of the case.

The Redwood National Park controversy is a good case in point. President Johnson asked the 90th Congress to protect the California coastal redwoods, largely owned by lumber companies, by establishing a Redwood National Park. A nationwide dispute erupted. A careful survey of the history of the dispute, which raged in the mid 1960's, shows that both conservationists and lumber companies were guilty of intemperate and distorted statements. Legislators, as always, were subject to conflicting pressures. Finally, within the federal bureaucracy itself there were signs of a struggle, as different agencies tried to build or maintain their separate domains in northern California. The real issue of whether or not a Redwood National Park was in the public interest was often submerged in a mass of conflicting claims, and seemed of secondary importance to many of the participants in the dispute.

The Redwood Controversy® simulates the dispute. Fictional witnesses and Senators have been created to avoid legal entanglements. Some significant aspects of the actual controversy have been omitted to scale the game down to the level of student sophistication. These elements were deliberately omitted:

1. The agreement to exchange title for federal lands in California for the California park lands needed for the National Park.
2. Arrangements by the federal government to give the lumber companies access to Forest Service lands to compensate to some degree for the timber resources bought from them.
3. The offer by the federal government to reimburse local governments for the tax revenues they would lose when private land became national park land.
4. Various modifications in the size of the proposed park that Congress scrutinized.

There is no reason to present these complications to the students. But keep them in mind to avoid erroneous generalizations during the post-game discussion.

Students might be interested in the outcome of the real redwood controversy. Of the several proposals submitted to Congress, two strong plans emerged. Plan 1, supported by President Johnson and Secretary of the Interior Stewart Udall, called for an 18 000-hectare park combining Jedediah Smith State Park, Del Norte Coast State Park, and approximately 10 000 hectares of private land. Plan 2, favored by the Sierra Club, was a 36 000-hectare park combining the two state parks, plus another, Prairie Creek Redwoods, with 31 000 hectares of private land.

A compromise was eventually worked out and signed into law October 2, 1968. Public Law 90-545 established a 23 000-hectare national park from the three California state parks and approximately 11 000 hectares of private land. Some timber companies that lost land were compensated with federal timber land near the park. This compromise park would fall somewhere between Proposals 2 and 3 in *The Redwood Controversy®*. A recent road map will show the location of the Redwood National Park.

Investigation 22-1
What will happen to the redwoods?

Role-playing games allow students to study issues that are generally avoided in conventional classroom situations. Expository prose at its best can only suggest the dynamic, complex nature of certain issues. But through role-playing, students can actually experience it. An important bonus is that students also learn how to bargain, compromise, and negotiate to resolve problems.

Students should not feel that they need to know every bit of information to play the game. Actually, very few Senators have a scientific background. They must decide on the basis of evidence presented at the hearing. Also, outside pressures may influence their vote.

This Investigation is an opportunity to focus student attention on skills learned earlier in the program. How much of the data presented is observation? How much is inference? Are inferences reliable evidence? Students will perceive the controversy in different ways, depending on their past experience or the role they play. Finally, the Senators evaluate the conditions and make a decision that they think will produce desirable outcomes. In essence they hypothesize that a proposal will produce a favorable change in another factor. The favorable change may be an improvement in the environment, reelection of the Senator, or increased income for a group. Only the hypothesis about reelection is testable in the context of the game.

Activity time: 3–4 class periods to introduce the game, play it, and discuss the outcome

Materials

The Redwood Controversy® is available from Houghton Mifflin Company. Contact your local sales representative or regional sales office. Only one game is necessary for a class.

Preparation

If possible, arrange the classroom furniture to look like a Senate hearing room. The Senators, with their name plates on their desks, would sit in a semicircle. The Senate Leader would be in the center of the semicircle. The witnesses would have desks facing the Senators.

Analyzing data

Focus on ways students can use their game experiences to understand current events and to guide their future behavior as responsible, concerned citizens. You might want to ask:

1. What factors seemed to influence the Senators most?
2. Which witnesses' presentations affected you the most? Why?
3. Did you convince another Senator to change his vote? How?
4. What factors should be considered before the government takes private lands?
5. Do you think it was luck that the proposal won. Or was it the best decision?
6. If you played the same role again, would you play it differently? How?

References

Camp, Dietrick, "Alaska's Great Oil Rush—The Story from the Scene." *U.S. News and World Report,* June 10, 1974. This article describes beginning of construction on the Alaska Pipeline.

"Deadline for the Redwoods." *Newsweek,* April 24, 1967, pp. 30–33. Highlights of the debate, plus a photo essay.

Friggens, Paul, "The Great Redwoods Controversy," *Readers Digest,* December 1966. A summary of arguments for and against the park at that time. (Debate continued for nearly two more years.)

Friggens, Paul, "The Great Alaska Pipeline Controversy." *Readers Digest,* November 1972. This article describes both pipelines and possible consequences of each.

"Heeded by Congress: the Cry of Save the Redwoods!" *U.S. News and World Reports,* September 23, 1968, p. 10. Summary of the final bill.

Merriam, L. C., "Redwoods for a National Park." *American Forests,* January and February 1968. A comprehensive discussion of the proposed park, including photos and bibliography.

"Redwood Purchase Unit is Sacrificed as Congress Sets up 58 000-acre Park." *American Forests,* October 1968, p. 56. A brief news item on the passage of the bill and the compensation of lumber companies with National Forest timber.

Film

The Redwoods. Association Films. New York. 20 minutes. Color. This is an Academy Award-winning documentary produced by the Sierra Club.

23 What can we do about pests?

Behavioral Objectives

The students will learn	*They will show they have learned*
1. that the use of the term "pest" depends both on the situation and the viewpoint of the observer.	1. by discussing how the classification of an organism as a pest depends on one's viewpoint. (Extend Your View 23-1)
2. about alternate ways to control pests.	2. by choosing ways of controlling pests that do the least harm to the environment. (Extend Your View 23-2)

Overview

This Investigation consists of a series of reports dealing with different aspects of the use and effects of pesticides. The material should be covered in group and class discussions. The class also can gather and present data on local pesticide problems.

Background

In the last 20 years, the most common method for controlling insects and other animal pests has been pesticides. The highly toxic nature of these substances is well known to agricultural research organizations and the general public. Consequently, one would expect that great care and restraint would be exercised in their use. All too frequently, however, there has been large-scale application of these poisons without adequate research into their total impact on the environment.

The agricultural pest problem has many sources. It is partly due to a degree of agricultural specialization where one crop is grown in large areas. Such an environment is ideal for the insect that eats only that kind of plant. The pest problem is probably also due to the philosophy that sees no natural limit to the productivity of a given area of land. This concept may have to be modified if its implementation depends on the large-scale use of pesticides.

Present chemical controls are of limited utility. Biological controls have been developed as an alternative, but their utility is neither universal or infallible.

Little has been done with selective breeding of crops for pest- and disease-resistance. Most commercial strains of vegetables are bred for size, attractiveness to consumers, and ability to be shipped without deterioration. Perhaps research should be aimed at producing more vigorous strains of vegetables and grains.

There is little doubt that market yields and quality have been increased dramatically by agricultural spraying. There is little actual data, however, on how much spraying is really necessary. It appears that many repeated applications of pesticides are merely "insurance sprays" and probably unnecessary. It is also quite evident that farmers are forced into following these procedures, in part, by consumer demands for unblemished or completely insect-free produce. Either consumers do not have the data to relate these perfect products with the attendant environmental contaminations or they still want the unblemished produce at any cost.

Investigation 23-1 Controlling pests

Each report presents a different perspective on the control of pests. Report 1 discusses how pesticides have been used to control a target insect only to have a second, and more destructive, insect population increase. Report 2 focuses on the problem of pesticides in food chains. Report 3 describes the resistance of organisms to pesticides. Report 4 presents alternatives to pesticides for controlling insects.

Each student should become familiar with the major ideas of each of these reports. You will have to choose among several possible methods of using the information.

1. Each group of students can be responsible for a panel presentation of one report. This presentation could include just the material in the book or additional material. If the latter approach is chosen, allow time for outside preparation.
2. Each student could be required to read some or all of the reports. For the discussion, you would choose the topics and guide the discussion, adding your perspective.

3. The topic of each report could be discussed by the class in general. Then the students could be allowed to select a topic or segment of a topic for additional library research and a subsequent report to the class.

Activity time: 3-6 class periods, depending on the amount of data available and the method of preparation

Materials (class):
additional data on local pest problems

Analyzing data

1. If an alternative is available, it should be considered. Any damage to the environment by spraying must be balanced against the harm caused by the pest.
2. Most people presently would not tolerate insect-damaged foods, even at lower prices. Present standards of food quality make it difficult to maintain the environment.
3. Pesticides seem to be useful in specific cases where the pest is an immediate and serious threat to a population. Widespread use of hard pesticides without precautions should be avoided. If possible, citizens should have a say in the decisions that are made, and all decisions should be based on the available data.
4. The alternative is some form of biological control.
5. Students might suggest studying predator-prey relationships among the insects to find ways to control them.

Optional activity

If your students investigate a local problem, they may want to share the information they find with others. They could

1. make a set of slides showing their data, or prepare a talk and present their data to other classes or to groups of interested adults.
2. make large charts, graphs, or posters to display around the school or in the community.
3. prepare and distribute pamphlets that give the results of their study.
4. put on a skit or play for other students in the school.

Whatever method is used for presenting the data, the students should look for help from well-informed people. That is, they could talk to the art teacher about posters or signs, to the school photography advisor or local photographer about pictures, or to the drama or English teacher about a play. They should look for the person who has the special knowledge to help them make the best presentation.

References

Dowden, Anne Ophelia. *Wild Green Things in the City: A Book of Weeds.* New York: Thomas Y. Crowell Company, 1972. A beautifully-illustrated discussion of the life cycles of plants that survive in cities.

Higdon, Hal, "New Tricks Outwit Our Insect Enemies." *National Geographic,* September 1972. Deals with a variety of methods, other than chemical pesticides, used to control pests. Focuses on using natural enemies of pests to control them.

Pesticides and the Environment. Columbus, Ohio: Ohio State University, Cooperative Extension Service, Bulletin 536, 1972. Contains materials covering several aspects of pesticides: need, economics, as pollutants and residues, and safety.

Puleston, Dennis, "Return of the Osprey." *Natural History,* February 1975. Before the ban on DDT, ospreys were threatened with extinction. Now their numbers are increasing.

24 Controlling pollution

Behavioral Objectives

The students will learn	*They will show they have learned*
1. that simulations are an approximation of reality.	1. by modifying *The Pollution Game* to make it more realistic. (Extend Your View 24-1)

Overview

The Pollution Game allows students to simulate the progressive contamination of our environment and then to try to reverse the contamination to preserve the environment. During this game, students will experience the antagonisms and frustrations of trying to change technology and social behavior. Teams should play the game at least twice. During the Extend Your View, players have a chance to design their own strategies to control pollution.

Investigation 24-1
The Pollution Game

By now the students have evidence of various kinds of pollution. They should ask, "Why isn't something being done?" The fact that society does not change quickly, and the reasons for this inertia, are often omitted from a student's education.

The Pollution Game should help students understand how their community functions. The players take the roles of influential citizens, make decisions, and initiate actions as if they were in the real-life situations simulated by the game.

People will win the real pollution game if they survive. In *The Pollution Game* survival is also the primary goal. Teams of students that neglect the quality of their environment will not win. Only those teams that correctly assess their situation and take appropriate action will be the winners. The individual winner in the class is the person accumulating the most money. In order for this student to enjoy his riches, he must act more responsibly than he might desire. For if he and his team allow pollution to get out of hand, he loses.

It is possible that at first all teams will lose because they ignore the level of pollution in the game. The outcomes for each team and for each class will vary widely. What is important is that the students should realize by the end of the game that solving pollution problems requires knowledge, initiative, cooperation, and money. Without serious attention, the problems only get worse.

Activity time: 3 class periods

Discussing the game and the rules should take less than one class period. Most classes will play the game the first time in a 45-minute class period. Some classes will require two periods. The length of play should be determined by the students.

Materials (groups of 4 or 5):

The Pollution Game is available from Houghton Mifflin Company. Contact your local sales representative or regional sales office. Ideally, you should have 6 or 7 games. But with fewer games (3 or 4), you could have half the class play one day and half the next.

Extend Your View 24-1
Making it better

The changes students propose for *The Pollution Game* should reflect current conditions in your community as well as worldwide problems. For example, if strict air pollution standards are in effect in your community, students could change the penalties to make them more realistic. If automobile inspection regulations require strict emission standards, the option for cheap tune-ups could be eliminated. Help your students analyze the proposals (*if-variables*) and the penalties (*then-variables*) to make these items simulate current conditions.

Appendixes

Appendix A
Keys for Extend Your Views

Answers to the Extend Your Views have been made as specific as possible. In many cases, however, the answers given are merely some of the acceptable responses. Students may need help in determining if they have met the objectives.

Appendix B
The metric system

The only units described are those that are used in the program. Your students may find the spelling of "metre" and "litre" unfamiliar. Explain that these are the internationally accepted spellings of these terms.

Appendix C
How to graph data

This is a self-contained program that allows students to develop graphing skills at any point in the course. However, it is best used when an individual student needs it. (Investigation 4-4 is the earliest point at which students are directed to use graphs.)

Many students have had experience with programed learning. They should be able to work through this program individually with little or no difficulty. If students ask for help with specific frames, direct their attention to earlier frames for aid in understanding the puzzling frame.

If you decide to use this program with the entire class, a class discussion afterwards should focus on both the construction of and rationale behind a line graph.

This program follows two commonly accepted mathematical conventions. The independent variable (*if-variable*) is placed on the horizontal axis. The numerical values of this variable are placed first when ordering the number pairs.

Choosing the scales is important in constructing graphs. Students should understand that the value of a scale segment is arbitrary, but all segments along one axis must represent the same number of units. The value of the segments may be varied to accommodate a larger or smaller range of data.

Students should also understand that the labeling of an axis need not begin at zero, but may begin close to the first data point. Students should also be careful when reading graphs to note whether or not a scale begins at zero. This is especially important when two or more graphs are being compared.

Appendix D
Learning to use a microscope

If your school has no microscopes, you should make arrangements with your high school or other nearby school to borrow at least six microscopes. Students should use the same microscopes throughout the year. A sense of "ownership" will result in a well-cared for microscope.

Although microscopes are first required in Investigation 10-1, students may find other situations in which microscopes would be helpful. Since some students may already have used microscopes, it may not be necessary for the whole class to perform the procedures as outlined.

Those students who have had no experience with microscopes may not understand the relation of the object and the image. Under a compound microscope, the image is both reversed and upside down. Have the students cut out a small capital "F" or other asymmetrical letter from a newspaper or magazine. When they observe the orientation of the letter with the microscope, they will discover the relation of the image to the object.

It is also advisable to have students look at a pair of crossed human hairs under high power. They can observe that both hairs will not be in focus at the same time. This will also demonstrate how the fine adjustment is used to focus on different depths of a "thick" sample.

Appendix E
Careers

As stated in the text, the careers described are but a small sample of those related to the subjects and skills of this program. Students can go to their guidance counselor or library for further information.

The United States government has devised a system to classify jobs. Each type of job is assigned a D.O.T. number. Jobs with the same D.O.T. numbers demand similar skills and interests. The jobs described in Appendix E have these D.O.T. numbers.

Accelerator operator D.O.T. 015.181
Agricultural engineer D.O.T. 013.081
Animal care technician D.O.T. 419.884 and 356.874
Aquatic biologist D.O.T. 041.081
Biochemist D.O,T. 041.081
Cooperative extension service worker D.O.T. 096.128
Ecologist D.O.T. 041.081
Experimental psychologist D.O.T. 045.088

Farmer D.O.T. 421.181
Fish and wildlife specialist D.O.T. 041.168
Fish culture technician D.O.T. 041.168
Food scientist (Food technologist) D.O.T. 041.081 and 022.081
Food technician D.O.T. 529.387
Forester D.O.T. 040.081
Forest technician D.O.T. 441.384
Horticultural technician D.O.T. 040.081
Horticulturist D.O.T. 040.081
Landscape architect D.O.T. 019.081
Livestock production technician D.O.T. 466.887
Marine life technician D.O.T. 041.081
Meteorologist D.O.T. 025.088
Microbiologist (Bacteriologist) D.O.T. 041.081
Nuclear reactor operator D.O.T. 015.380
Nursery manager D.O.T. 406.168
Orchard and vineyard technician D.O.T. 404.181
Park and recreational land management specialist D.O.T. 188.168
Pest-control technician D.O.T. 389.884
Pharmocologist D.O.T. 041.081
Product tester (no number available)
Radiation monitor D.O.T. 199.187
Range manager D.O.T. 040.081
Sociologist D.O.T. 054.088
Soil conservationist D.O.T. 040.081
Soil scientist D.O.T. 040.081
Systems analyst D.O.T. 012.168
Technical writer D.O.T. 139.288
Urban planner D.O.T. 199.168
Veterinarian D.O.T. 073.081
Wastewater-treatment plant operator D.O.T. 599.782
Wood scientist and technologist D.O.T. 040.081
Zookeeper D.O.T. 356.874

NOTES

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You and the Environment

An Investigative Approach



You and the Environment
An Investigative Approach
is a major revision of the 1974 edition of *Life Science Investigations: Man and the Environment.* For historical information on the original edition, see Appendix F.

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You and the Environment

An Investigative Approach

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Preface to the teacher

You and the Environment is a direct descendant of *Man and the Environment.* The Investigations have been revised on the basis of feedback from teachers, and updated to reflect changing environmental problems. There are several new Investigations that focus on the students' immediate environment and that incorporate, more explicitly, the role of energy in environmental problems.

Behavioral objectives are presented to the students to aid them in directing their learning in each set of Investigations. The Extend Your View items present new situations to which students are to apply what they have learned. These items are keyed to the behavioral objectives.

Gary D. Day, *Director*

Preface to the student

This program will help you learn more about your environment and how you affect it. Instead of just reading, you will investigate the environment through your own activities. Many of the questions you investigate will be your own.

Often you will work in small groups. Sometimes you will work alone. Your teacher will help you set up your investigations, but you will find your own answers. By the time you complete this course you will be able to

1. ask questions about the behavior of organisms.
2. set up experiments to answer your questions.
3. find out what environmental conditions affect organisms.
4. suggest a variety of ways to deal with environmental problems.

Dennis L. Harvey, *Coordinator*

Key to Pronunciation Guide

Some words in this book that may be hard to pronounce are followed by a pronunciation guide in parentheses. The guide syllable printed in capital letters should be given the greatest emphasis when you say the word. In the key below, the first column is a list of the letters or marks used in many dictionary pronunciation guides, with an example of the sound that each one stands for. The next column shows how the same sound appears in the guides in this book. The third and fourth columns list examples of words that contain that sound, and their pronunciation guides.

Letter or mark	Appears in this book as:	Example	Guide
a (hat, map)	a	analyze	AN uh lyz
ā (age, face)	ay	rate	rayt
â (care, air)	ai	share	shair
ä (father, far)	ah	farming	FAHRM ihng
ch (child, much)	ch	chain	chayn
e (let, best)	eh	meadow	MEH doh
ē (equal, see, machine, city)	ee	leaf	leef
		tangerine	tan juh REEN
ėr (term, learn, sir, work)	ur	earth	urth
i (it, pin, hymn)	ih	insect	IHN sehkt
ī (five, ice)	y	life	lyf
	eye	island	EYE luhnd
k (coat, look)	k	corn	kawrn
o (hot, rock)	ah	moth	mahth
ō (open, go, grow)	oh	echo	ehkoh
ô (order, all)	aw	form	fawrm
		fall	fawl
oi (oil, voice)	oy	soil	soyl
		poison	POY zuhn
ou (house, out)	ow	mouse	mows
s (say, nice)	s	mice	mys
sh (she, revolution)	sh	pollution	puh LOO shuhn
u (cup, butter, flood)	uh	muddy	muhdee
		blood	bluhd
u̇ (full, put, wood)	u	pull	pul
		book	buk
ü (rule, move, food)	oo	view	vyoo
zh (pleasure)	zh	measure	MEHZH uhr
ə (about)	uh	adapt	uh DAPT
(taken, purple)	uh	bubble	BUHB uhl
(pencil)	uh	citizen	SIHT uh zhun
(lemon)	uh	lion	LY uhn
(circus)	uh	focus	FOH kuhs
(curtain)	uh	mountain	MOWN tuhn
(section)	uh	question	KWEHS chuhn
(fabulous)	uh	famous	FAY muhs

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Unit ONE

Investigating living things



1

Asking better questions

After you complete these Investigations, you will be able to

1. ask questions that you can investigate for yourself.
2. ask questions that focus on the puzzling or unusual parts of an event.

How many times have you asked people "How are you?" Did you really want to know about their health or did you just want to greet them? Some questions ask for a reply, but not an answer. There are other questions that ask for simple answers. "What time is it?" "What's for dinner?" "Who is the new person in class?" Sometimes you cannot get an answer right away. "Who will win the game tonight?" "What will I be doing next summer?" "Who will win the election?" These questions still have simple answers. All you have to do is wait.

Some questions are a little harder to answer. "Did this traffic jam come from the concert downtown?" "Did the rainstorm break that tree limb?" "Where does our drinking water come from?" Then there are questions that may never be answered. "Why does one person learn to talk sooner than another?" "Is there life on other planets?" "What does an atom look like?"

In science it is important to ask questions that can be investigated. That is what you will be doing in these Investigations.

Investigation 1-1
What is a useful question?

To help solve problems, you must ask the right questions. To answer questions, people gather evidence or **data** (DAY dah). Usually they follow a plan or procedure to collect the data. Some questions are easier to investigate than others. Are questions that can be easily investigated similar in some ways? Here is a way to find out.

Materials
tracing paper
ruler

Gathering data

If your students are not familiar with the metric system, Appendix B should help them.

Using a ruler, draw two parallel lines 12 centimetres (cm) long and exactly 2 cm apart on the tracing paper. Place your paper over the drawing. Center your lines between the sides of the drawing. What do you see?

To understand what you see, you probably need more data. The questions about the drawing may help you. Read these questions and try to answer them. Use the materials provided. Do not ask your teacher or classmates to give you answers. This is not a test, and the results will not be graded. The idea is simply to find out which questions you can easily investigate.

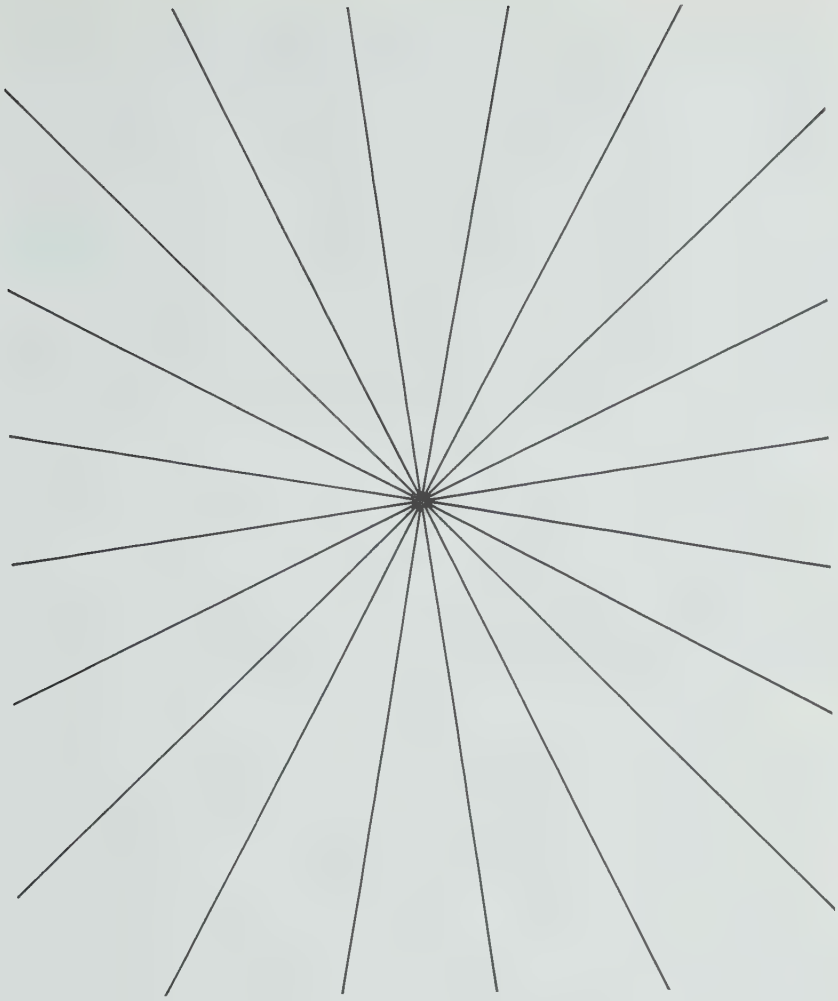
List your answers to the questions in your notebook. This is a record of your data. You will refer to it later.

Analyzing data

Discussions of the Analyzing data sections of the student text are included in the appropriate sections of the Teacher's Manual.

After gathering data, you can analyze it to make sense of it. To **analyze** means to examine the parts of something carefully to see how they relate to one another. These questions will help you analyze your data. Discuss them with your class.

1. Do you now have any idea why the lines appear curved? If you do, which questions led you to this information?
2. How are these helpful questions similar?
3. Which questions, if any, were you unable to answer? What made these questions too difficult to answer?
4. Did any questions lead to information that did not help you understand the "curved" lines?
5. Have you thought of any new questions that might lead to more useful information? How are these questions similar?



Questions about the drawing

1. Are the two "curved" lines really curved?
2. Why do you see the lines as curved?
3. How long are the "curved" lines?
4. Do other people see the two lines as curved?
5. Suppose twice as many lines crossed in the center of the drawing. How would the two "curved" lines appear?
6. Does your brain make you see the two lines as curved?
7. What is this drawing supposed to mean?
8. What would the two "curved" lines look like if they were slowly moved across the drawing from left to right?
9. Suppose you held the figure at eye level and sighted across it instead of looking straight down at it. Would the two lines still look curved?
10. Do the two lines still look curved when they are drawn closer together?

These items also have some metal parts and a steering mechanism. They each function as a means of transportation. If some students are having difficulty with the term "property," give them another group of related items to work with.

All things have certain features or **properties** that help identify them. A group of objects may have some properties in common. Consider a bicycle, a car, a motorcycle, and a bus. Each of these items has wheels, a seat, and brakes. What other properties do they have in common?

You have been analyzing questions that are easy to investigate. What are the common properties of these questions? (Check your answers to Questions 2 and 5 on page 2.) List these properties in your notebook. Many times during your study of *You and the Environment* you will ask questions. Use this list as a guide to help you ask better questions.

Investigation 1-2
Asking questions about people

You already know quite a bit about people. But you may not be able to explain both parts of this Investigation. By asking questions and answering them, you may learn something new about yourself and other people. Remember to think of questions that you can answer for yourself.

Materials
"test paper"
list of "memory words"

Gathering data

There are two parts to this Investigation. Everyone in class will try both activities. Then you will get to choose one activity to investigate further.

Students usually respond to this activity with a great deal of enthusiasm and spontaneity. They may want to bring in a few foods: fruit, raw carrots and celery, salt, vinegar, small candies (such as Life Savers), peanut butter, crackers, salad oil. Students can either bring in items from home for the next class or take some "test paper" home.

Test paper
Take a piece of "test paper" and lick it once. Your teacher will do this, too. Examine the paper after about a minute. Then compare it with your classmates' and teacher's test papers.

Memory words
For this activity the class separates into two groups. Your teacher will place a list of words face down on your desk. Do not turn the list over until you are told to. You will have one minute

to try to memorize the list of words. Then turn the list face down again. Write all the words you can remember on another sheet of paper.

Check to see how many words you remembered correctly. The order of the words is not important. Write down the number of words you remembered. Have two or three people in your group add the numbers to find your group's score. Compare your group's score with the other group's score.

If the groups are not equal, compare the averages of the individual scores in each group. Do not tell students that the lists differ, but let them examine both lists later when formulating questions.

Which of the activities that you did interests you more? Can you explain the results of this activity, or do you need more information? What questions will help you seek the information you need?

First, write down what is unusual or puzzling about the activity. It helps to say just what the problem is before you ask more questions about it. Then make a list of questions about the activity. You want questions that might help you find out what is going on. Leave space after each question for writing an answer. Finally, gather any data you need to answer your questions.

To answer their questions, students may want to test new subjects who are not familiar with the activity. You could ask other teachers for several minutes of their class time for testing.

Analyzing data

You have two things to analyze. One is the outcome of your activity. The other is the list of questions you asked. Analyze your own list of questions and answers. Find the questions that helped you get useful information. Then find out what these questions have in common.

Some of your classmates analyzed the same activity you did. Discuss your questions and answers with them. These suggestions may help you get started.

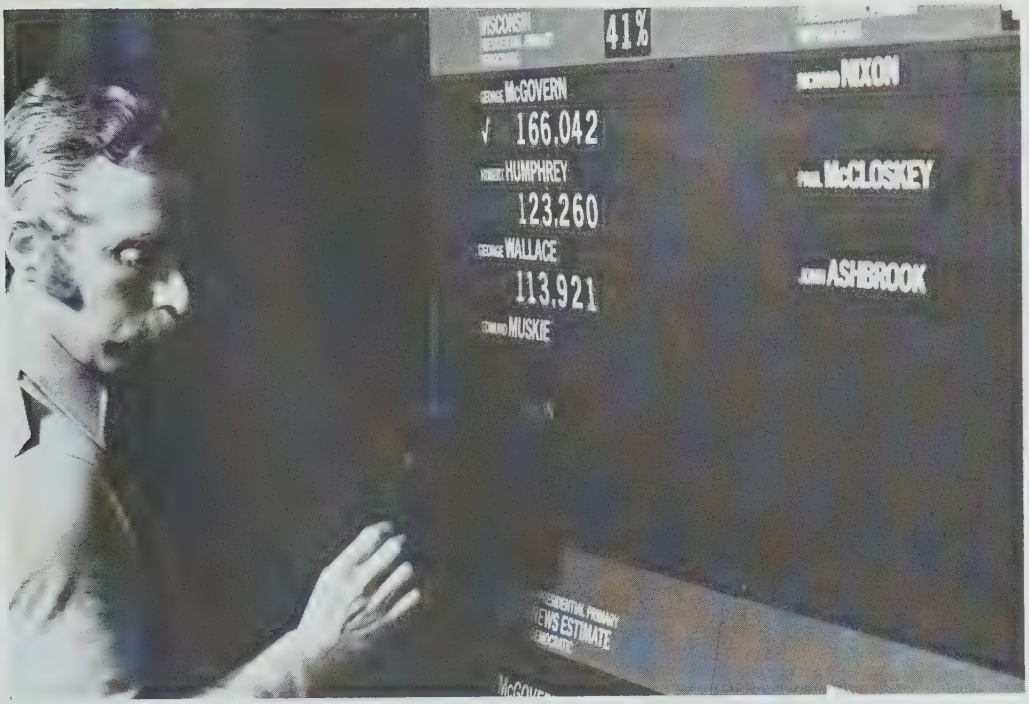
It will probably be more efficient for students to work in small groups to analyze their questions before holding a class discussion. The students will probably need to refer to their list of common properties of questions that can be investigated.

1. Did the answers to your questions help you understand the activity?
2. Were there questions that you could not investigate? Can you change these questions so they can be investigated?
3. Did you ask questions about the entire activity instead of part of it? Do you think these were helpful questions?
4. Did you ask any questions that did not need specific answers such as "Yes" or "No" or an amount? Do you think these were helpful questions?
5. Were there any questions you could not answer but still think are useful questions? How are these questions similar to the ones you could answer?

Students will have some tentative answers to their questions as a result of this activity, but may see the answers as absolute. Avoid evaluating their judgments or offering knowledgeable explanations. The idea of the tentative nature of solutions will be developed throughout the course.


Canon







What kinds of data are these people gathering and recording?


377·829

Extend Your View 1-1
How can this be?

There are Extend Your Views at the end of each set of Investigations. These items will show you if you have learned the skills and ideas in the Investigations. These skills and ideas are listed at the beginning of each set of Investigations. If you need more practice, your teacher can suggest ways to help you improve.

The Extend Your Views are not tests for determining your grade in the course. They are a way for you to evaluate your own progress. First write down your own answers. Then compare them with the answers in Appendix A.

Have these Investigations helped you to ask questions you can answer for yourself? Can you focus on the puzzling or unusual parts of an event? Examine the situation in the photograph. In the next ten minutes, write as many questions as you can to help you explain what is happening. Imagine that you are at the scene in the picture, trying to answer your questions. The people in the picture will talk to you, but they will not explain what is happening. List your questions in your notebook. You may use your list of properties to help you. Now turn to page 318.

Some questions just won't leave you alone.



© 1961 Saul Steinberg
From *The New World* (Harper & Row)
Originally in The New Yorker

2

Making observations and inferences

After you complete these Investigations, you will be able to

1. use more than one sense to make observations.
2. record your observations clearly.
3. make quantitative observations whenever possible.
4. make inferences from quantitative data.
5. make inferences about an unfamiliar situation.
6. divide a list of statements into observations and inferences.

Look at the open locker in the photograph. What things can you see in the locker? What can you tell about the person who uses this locker? Do you think the locker belongs to a student or a teacher? Is the person male or female? Is the person neat or sloppy? Can you tell what season it is? Can you tell the time of day? What items in the locker helped you to make your decisions?

You could tell the contents of the locker by observing the photograph. To answer the other questions, you had to make some guesses, or inferences. In these Investigations, you will learn more about observations and inferences. You will learn how to make them and how to tell the difference between them. You will use your skill in asking questions to help you in these Investigations.

Investigation 2-1
What can you observe about people?

You have probably seen the people in your class many times. But have you ever watched any one of them carefully? In this Investigation you will.

Gathering data

Imagine that you and your classmates are scientists, visiting from another planet. You have a short time to learn all you can about humans by observing just one subject. Imagine that the other scientists from your planet are doing the same thing with other subjects. Later on you will have a chance to compare observations. All together, you should be able to discover many things about humans.

If some students finish quickly, help them see that other kinds of observations are possible. Often they may have missed details or entirely overlooked the subject's behavior.

Pick out a person sitting near you in the classroom. He or she will be your subject for observation. Observe your subject carefully for about 15 minutes. Make a list of your observations in your notebook. Make your notes short and neat. Other people may be reading them.

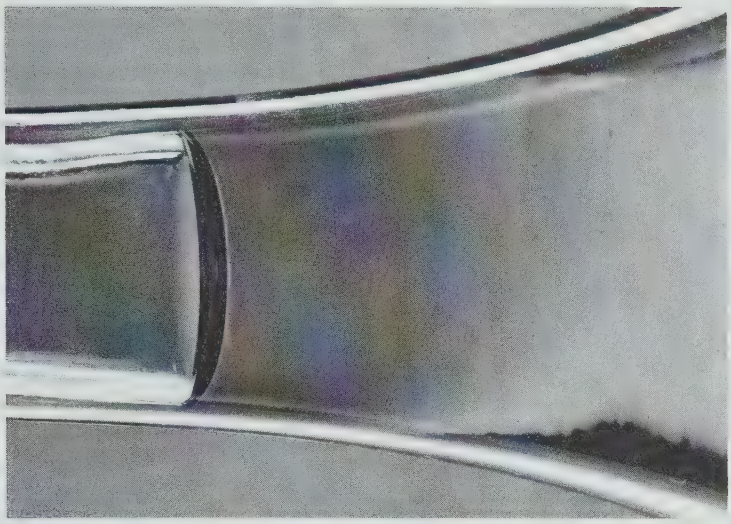
Analyzing data

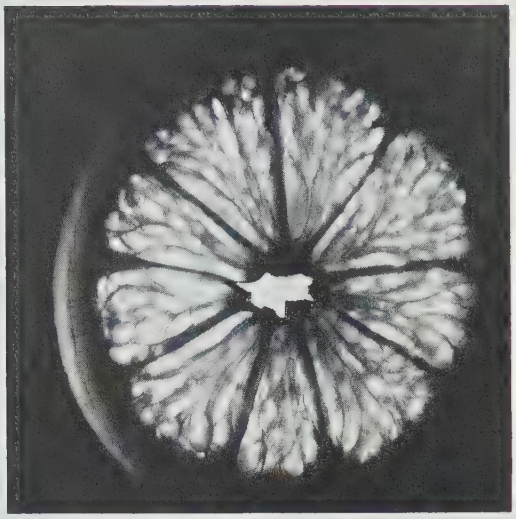
Students may take the matter of two eyes, two ears, a nose, and a mouth for granted and not include them in their list. Such things are often essential in identifying an organism.

An **observation** is something you directly see, hear, taste, smell, or feel. Did almost everyone observe the same things, such as hair color and eye color? Were there some properties that no one remembered to mention, for example, number of eyes or fingers? Did anyone group his observations into reports on the subject's appearance and reports on the subject's actions?

Emphasize the potential value of quantitative observations if they appear in the students' lists. But do not introduce quantitative observations yourself until Investigation 2-3.

1. Which written observations are clear in their meaning? Do some give an incorrect picture? A good test of clearness is to imagine reading your observations to a friend over the telephone. Would your friend be able to identify the subject from your description?
2. Were all your observations based on sight alone? Or did you use other senses such as hearing?
3. What value is there in making observations in a planned, orderly way? How could you improve the order of your observations?
4. Have some of your notes described more than you actually observed?







Try to identify the objects in the photographs on this page and on page 14.

(above left) neck of bottle, (above right) lemon slice, (left) soap bubbles



(top) wood block and print, (center) a multiple exposure of one Ping-Pong ball, (bottom) ice cube





Investigation 2-2
What can you infer from a comic strip?

Sometimes you go beyond simple observation. You make a guess about an observation that may or may not be true. Such a guess is an **inference** (IHNF ruhns). Suppose you went outside and observed that the sidewalks were wet. You might infer that it had been raining. "Wet sidewalks" is an observation. It can be directly seen or touched. "Had been raining" is an inference. It was not observed directly. In fact, someone might have sprayed the sidewalks with a hose, or maybe a water pipe broke. If you use your imagination, you might think of a dozen explanations for a wet sidewalk.

Now consider this situation. Your school's fire alarm rings during a class. You hear the alarm. That is an observation. If you say to yourself, "Another practice drill", that is an inference. It may be the right reason for the fire alarm. But there may be other reasons—possibly a real fire. In that case you might observe other things as you leave the building. These will tell you if your original inference was correct. Which inference would seem better if you smelled smoke?

Another possibility is a false alarm. The students might see fire trucks, but no smoke or flames.

Materials
a cartoon or comic strip

Gathering data

Look at the comic strip you brought in. Spend a few minutes studying it. Make some observations and inferences. For example, can you infer anything from facial expressions? How does the artist represent a sleeping person? How is motion shown? Can you infer strength or power from a character's appearance? What other clues does the artist give you?

Divide your notebook page into two columns. Label one "observations" and the other "inferences." Spend about ten minutes writing down the observations and inferences you make about your cartoon. Exchange your comic strip or cartoon with someone else and repeat the procedure.

Analyzing data

Making inferences is a skill. You can improve your skill by practice and by discussing your results with others. Compare your list of inferences with your partner's for the same cartoons. What observations led to each inference?

1. How can you tell the difference between an observation and an inference?
2. Did any two people make different inferences from the same observation?
3. Is there any way to show that an inference is correct?
4. Did anyone miss the point of any cartoon? Was this because he or she did not make the inferences that the cartoonist had in mind?

What can you infer about the people in these photographs? Are all your inferences based only on what you can see?

The people in the top photograph should be unfamiliar to the students. Any inferences must be based only on observation of the photograph.

Students may recognize some of Johnny Carson's guests. Their knowledge of these people will affect any inferences.





Investigation 2-3
Observing other living things

In Investigation 2-1, you practiced observing your classmates. Perhaps you were surprised to find how much you could observe about people you knew well. In this Investigation, you will make observations and inferences about some less familiar organisms. An **organism** is any individual living thing. You will improve your skill at making observations and inferences.

Materials
plant and animal
metrestick or ruler
magnifying glass
balance

Provide the instruments specified, but allow the students to choose which, if any, instruments to use.

During the activity, watch for chances to instruct individuals in the proper use of the balance and other instruments. If possible, let students discover by themselves how the instruments work. Consider providing a programed list of instructions with the balance and a few inanimate objects to practice on.

Gathering data

Start with either the plant or the animal. In 15 minutes, make as many observations and inferences as you can about the organism. Rulers, balances, and magnifying glasses are useful in making observations.

Now, turn your attention to the other organism. Take another 15 minutes to make observations and inferences about this organism. Record your observations and inferences in separate columns as you did in Investigation 2-2.

Analyzing data

1. Are all your observations really observations? Are some really inferences?
2. Did you make more than one inference from some observations?
3. A **quantitative** observation reports a quantity or measurement. Which of your observations are quantitative?
4. An observation that does not include a measurement is called a **qualitative** observation. It reports qualities or properties. Which of your observations are qualitative?
5. Which observations are less likely to be misunderstood—quantitative ones or qualitative ones? Why?

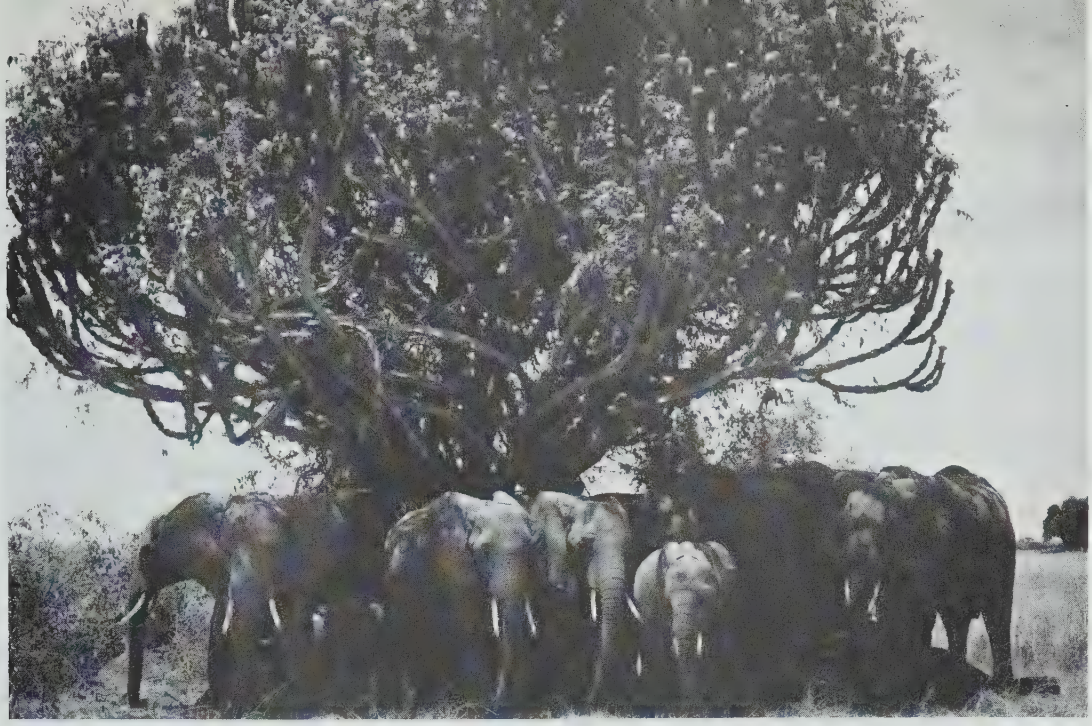
Try to develop the idea that quantitative observations are preferred when possible. They are more explicit than qualitative observations, and they are the result of specific, repeatable procedures.



Look at the photographs on these two pages. What inferences can you make? Do cheetahs and raccoons climb trees for the same reason? Which people in the square are natives and which are visitors? Why are the elephants standing under the tree? At what time of day are the horses drinking?

The cheetah may have climbed the tree to look for prey. The raccoon may either be looking for food in the tree or hiding from enemies. The people feeding the pigeons are probably tourists; the people selling items are probably natives. The elephants are probably looking for shade. From the shadows in the photograph of the horses, students will probably infer that it is not noon. It may be early morning or late afternoon.











Investigation 2-4
Making quantitative observations

In Investigation 2-3, you learned that quantitative data is less misleading than qualitative data. Is it better to know that a sweater costs $5 or to simply know that it is "a bargain"? Is it more useful for a doctor to know your exact temperature than to know that your forehead feels hot? What quantitative data can you gather about people?

Gathering data

These questions should help you get started. They are general questions about people. You will first have to change the general questions into ones you can investigate. For example, Question 1 is a general question about height. You could change the question to: Are the boys in my class taller than the girls? Or, what heights occur most often in my class?

Encourage students to think of other general questions that can be used. Avoid questions concerning heartbeat rates. This topic will be investigated in great detail in later investigations.

Students will probably work more effectively in small groups. Or the entire class may want to gather data on one or two questions.

1. How tall are people?
2. Do the lengths of hands and arms vary?
3. Do handspans vary?
4. How long is the hair on a person's head?
5. How big is a human head?
6. How fast do people walk?
7. Do all people see equally well?
8. Do all people hear equally well?

Measure and record as much quantitative data as you can. Decide for yourself what methods to use. Take several measurements for each subject. Your teacher will provide equipment.

Twice should be sufficient unless the two measurements vary greatly. Then three or four trials should be averaged.

Analyzing data

Describe your method of gathering data. If you used more than one method be sure to describe each one. Was everyone in your class able to collect quantitative data? Do all observations made by the same method on the same subject give exactly the same result? If not, you will need to report an average. Suppose you measured the height of a classmate three times. You would add the heights and divide by three to get the average.

Arrange your data in a table or some other form that is easy to understand. Sometimes it is useful to know the range of your data. The **range** is the difference between the largest measurement and the smallest measurement. The range shows the amount of variation in the data. Suppose you measured these four heights: 152 cm, 148 cm, 161 cm, 142 cm. You could arrange the data from highest to lowest.

161 cm
152 cm
148 cm
142 cm

Subtracting 142 cm from 161 cm, the range is 19 cm. Will finding a range help you analyze your data?

Report your group's results to the class. Were you able to answer the general question you began with?



Instruments improve our ability to observe. Using the photographs, pick the more accurate drawing.

The drawing on the right is more accurate.





Extend Your View 2-1
Describing an animal

Can you use more than one sense to make observations? Can you accurately record your observations? Your teacher will show you an animal. In five minutes, make as many observations as you can. Write your observations on a sheet of paper.

Extend Your View 2-2
How fast do people breathe?

Have you learned to make quantitative observations? Change the title of this Extend Your View into a question you can investigate. Then describe how you would investigate your question. Make sure your method gives you quantitative data.

Any method is acceptable if it achieves the desired end of producing quantitative data that is reasonably reliable. A method would be considered reliable if other observers could repeat it and get similar results.

The idea of controlling variables will be considered later in this unit, so do not introduce this topic now.

Extend Your View 2–3
An inference about fish

Can you make inferences from quantitative data? Jeff decided to study one of the fish-tanks at school. It had plants and rocks at the bottom. He counted the number of fish in the top half of the tank and the number of fish in the bottom half of the tank. He waited a minute and then counted the fish again. Jeff repeated this procedure several more times. Here is a record of his observations.

Number of fish in the tank.
Trials one minute apart.

Trials	*Number in upper half*	*Number in lower half*
1	*3*	*9*
2	*0*	*12*
3	*3*	*9*
4	*3*	*9*
5	*3*	*9*
6	*2*	*10*

Make two inferences from the data. Your inferences should help to explain the data.

Students should have an opportunity to explain their answers. Even in relatively simple situations, it is impossible to predict all the inferences that might be made by a class.

Extend Your View 2-4
What can you infer?

The game is rugby. There are 15 people on each team, but they are not all visible in this photograph. The game includes passing as well as kicking.

Can you make inferences about an unfamiliar situation? From what you observe in the photograph, try to infer answers to these questions. Write down the observations that support your inferences.

You can use other pictures to give students additional chances to master this item. Sources of good items include *Natural History*, *National Geographic*, *Scientific American*, and *Science World*. A good picture for this purpose should be large, have a lot of clear detail, and depict a provocative situation.

1. In which direction is each team moving?
2. Does everyone on the team have the same job?
3. What is the role of the man on the far left?
4. Are the players allowed to touch the ball with their feet? with their hands?
5. Which team is winning?

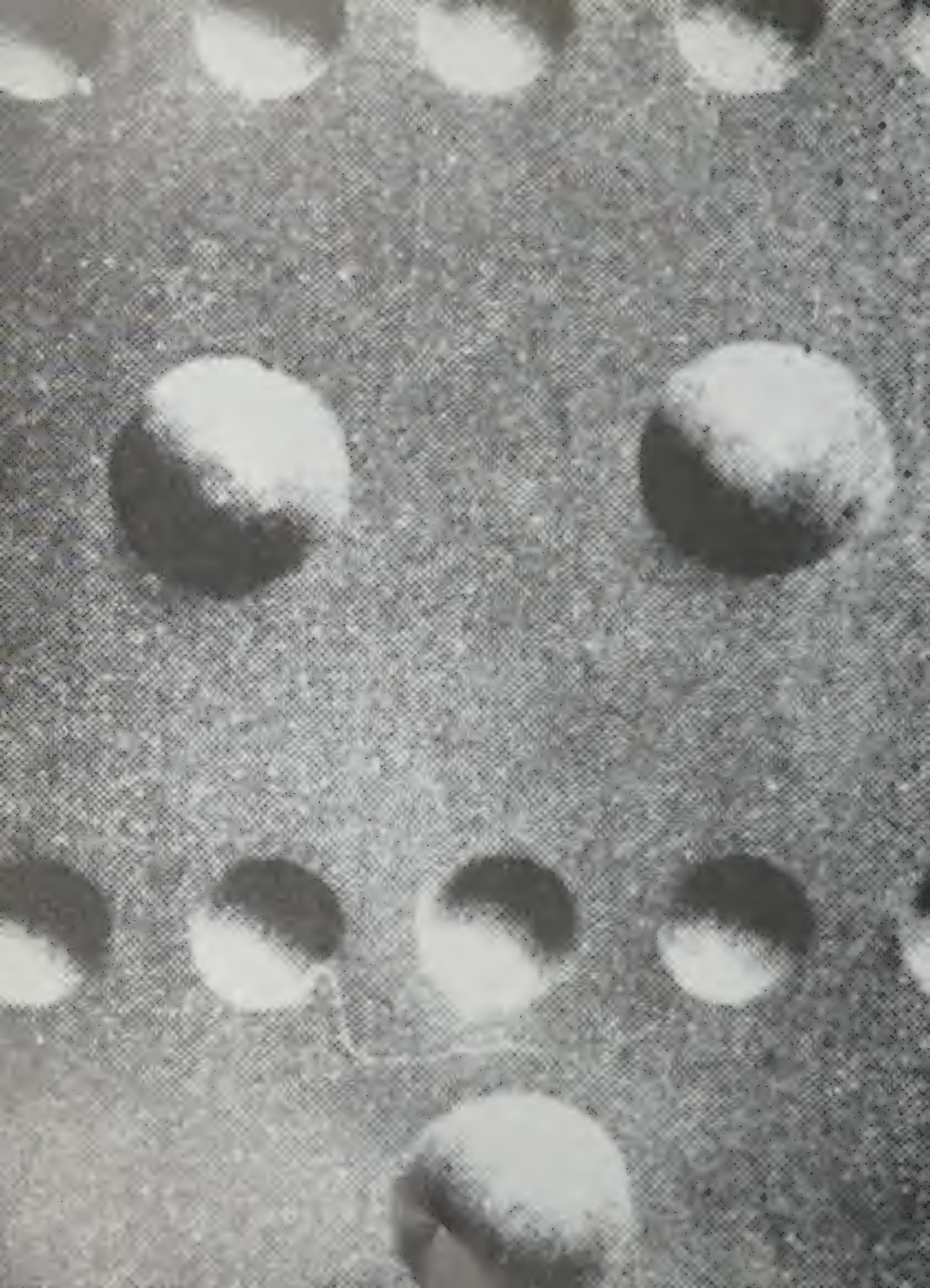


Extend Your View 2-5
Observation or inference?

Can you divide a list of statements into observations and inferences? Here are ten statements about the photograph. Decide which of the statements are observations and which are inferences. Copy the statements on a separate sheet of paper. Mark each statement either **O** for observation or **I** for inference. Do not write in the book.

1. There are two elephants.
2. Birds eat grass.
3. The elephant is not bothered by the bird on its back.
4. The elephant on the right has longer tusks.
5. The light is coming from the right.
6. There are seven birds.
7. Elephants travel in pairs.
8. The elephant on the right is older.
9. The elephant on the right is larger.
10. Birds travel in groups.





3

Perceiving the environment

After you complete these Investigations, you will be able to

1. infer that living things will have different perceptions if they use different sense receptors.
2. use measurements to improve the accuracy of perceptions.
3. use past experience as well as sense data to analyze perceptions.
4. infer how different people might perceive the same object or event.

There is an old saying, "Seeing is believing." How true is it? Look at the photograph on the opposite page. Which of the circles do you think are "hills"? Which do you think are "valleys"? Now turn the book upside down. Do you still agree with your choices?

Sometimes making observations is complicated. The photograph did not change. But what you saw in the photograph did change. Your **perception** of the photograph, or the sense you made of it, changed. In these Investigations, you will find out more about perception.

This pattern was developed to test changes in depth perception. Most people naturally assume that the light is coming from the upper right. When the photograph is viewed upside down, the "hills" appear to be "valleys."



Investigation 3-1
How do animals get information?

You might take your class outside and have them blindfold themselves to increase their awareness of sounds and smells. The students might discover that they do not use all their senses to full capacity because they depend so much on sight.

Some parts of your body specialize in receiving messages from your **environment,** or your immediate surroundings. These parts are called **sense receptors** (ruh SEHP tuhs). Each part is sensitive to one type of signal. For instance, your eyes are sensitive to light and your ears are sensitive to sound. People have five major senses: sight, hearing, taste, touch, and smell. We use our senses to perceive, or become aware of, our environment.

Gathering data

Do other organisms have the same senses that we do? Read about four different kinds of animal and how they perceive their environments. Be prepared to discuss what you have read.

Bat flight in the dark

Many animals can tell where they are by using their eyes. Some animals can tell where they are by using their ears. They make



How does the bat locate the moth?

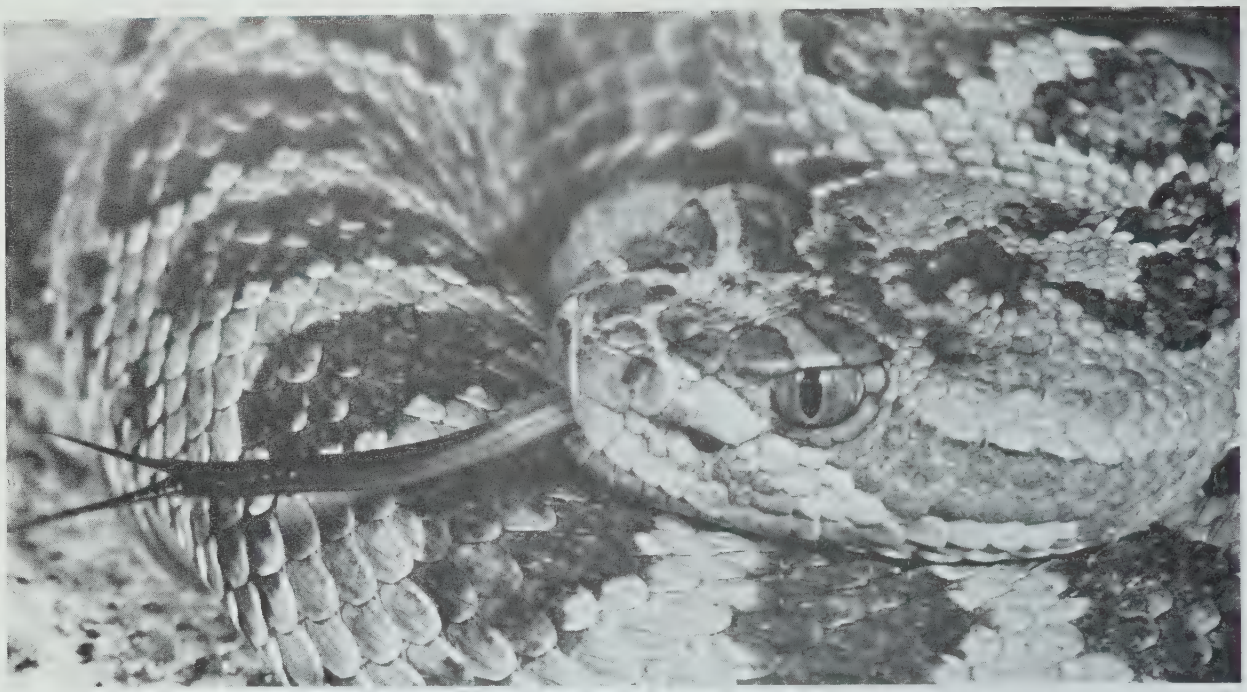
sounds and then listen for the echoes from nearby objects. Bats and porpoises can use sound in this way. Echolocation (from the words "echo" and "location") helps them find food and avoid obstacles.

A bat finds its way through the air by squeaking a series of high-pitched sounds and listening for the echoes. The returning sounds are interpreted by a part of the bat's brain. This is similar to the way radar works. A bat can tell the size, shape, and distance of objects around it, even in the dark. If the object is an insect, the bat may fly toward it. If the object is a tree or a wire, the bat will fly around it.

Bats have a large voice box for making high-pitched sounds. Bats also have large ears that can detect very soft sounds. They can even hear the sound made by a flying moth. Imagine, for a moment, that you could use echolocation. What would be your perception of your environment? What could you do that you cannot do now?

Snakes that hunt by heat

There is a group of snakes that can locate warm objects by the heat these objects give off. This group of snakes includes rattlesnakes, pit vipers, and the blind boa, which lives in caves. In front of their eyes, these snakes have special pits or holes that



Try to find the rattlesnake's heat pits.

are sensitive to heat. These receptors can spot a warm object in cool surroundings up to half a metre (m) away.

Since these snakes eat warm-blooded animals, such as mice and birds, these receptors help them to find food. (Warm-blooded animals usually have a body temperature higher than their surroundings, especially at night.) Because of the location of the pits, snakes can sense heat only from straight ahead. This helps the snake line up its head with its target.

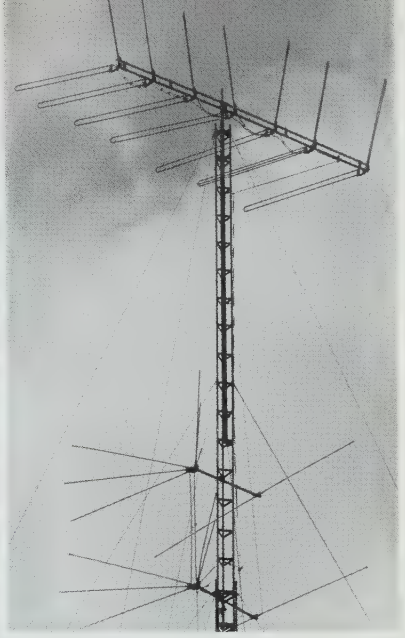
Would a rattlesnake use its heat-sensitive pits more during the day or during the night? How would you perceive the room you are in right now, if you had the rattlesnake's special receptors?

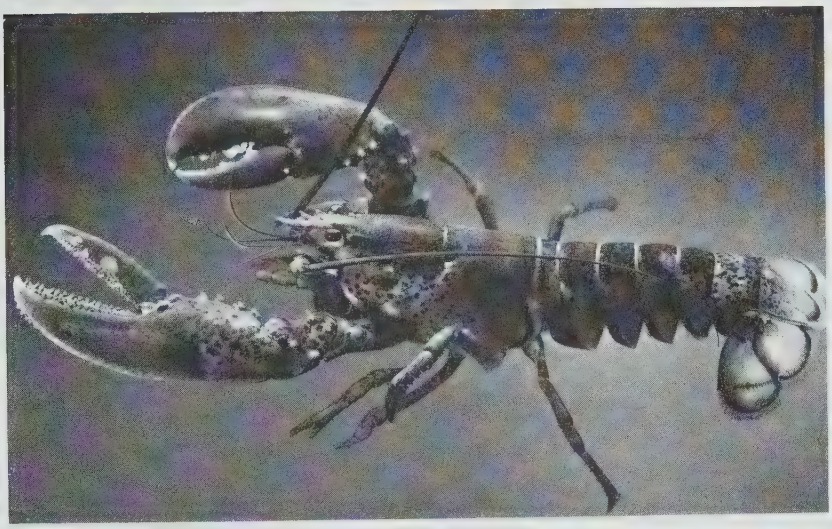
Snakes (and other reptiles) that live in warm climates are nocturnal, foraging and feeding at night. At night warm-blooded animals are significantly warmer than their surroundings.

Communication between moths

A French biologist, Fabre (FAH br), was studying a female moth. He placed the moth in a cloth cage near an open window in his house. Within 15 hours, 60 males of the same kind of moth gathered around the cage. Fabre wanted to find out how the male moths located the female. He placed the female moth near the same window, but this time in a tightly-closed glass jar. Although she could still be seen by other moths, no male moths appeared.







What do the antennae of moths, lobsters, and televisions have in common? How are they different?

Each of these antennae can receive signals, but the type of signal that can be received is specific to each antenna.

Fabre repeated these experiments with another type of female moth and got the same results. When the female was in a cloth cage, she attracted males from as far away as several kilometres (km). But when she was placed in a clear glass jar, no male moths appeared.

Moths have receptors called antennae (an TEHN ee) on their heads. Fabre observed that males whose antennae were removed could not locate the female in either the cloth or glass cage. He inferred that perhaps the female moths produce vibrations. These vibrations might be detected by the antennae of the male moths. The males could then locate the female. Males without antennae would not be able to locate females because they could not sense the vibrations.

The students might suggest an experiment using freshly-killed female moths or an extract from female moths. Also, an experiment could be set up when the wind is blowing to see if there is a tendency toward "downwind" responses.

One piece of evidence still puzzled Fabre. Male moths also flocked to the open jars from which females had just been removed. Maybe the female had an attractive odor. Could the males detect the odor several kilometres away? Can you think of a way to find out if the males are attracted by an odor or by a vibration?

An electric perception system

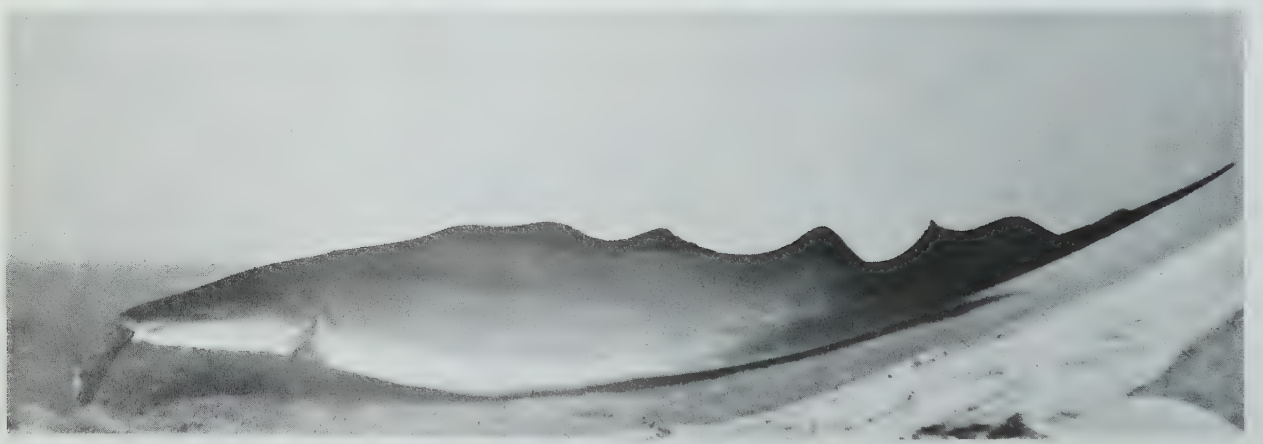
Gymnarchus niloticus (jihm NAHR kuhs ny LAH tih kuhs) is a fish that lives in muddy African rivers. *Gymnarchus* feeds mostly on smaller fish. Studies show that it feeds at night and hides under logs or rocks during the day.

Gymnarchus seems to react only to extremely bright light. This fish is reportedly able to distinguish between living and nonliving things by the degree to which they conduct electricity.

Scientists observing *Gymnarchus* in a darkened aquarium found that its movements are well controlled. When it is feeding, it never bumps into the walls of the tank or other obstacles. *Gymnarchus* cannot see in the darkened tank, but it moves easily forward or backward.

Scientists have known for some time that this fish can produce weak electric currents. But they did not know the exact method. One scientist placed *Gymnarchus* in a tank that had equipment for measuring electricity. He discovered that the fish surrounds itself with a weak electric field.

When *Gymnarchus* is near an object, its electric field is disturbed. There are special receptors in its head that sense any change in the electric field. In this way, *Gymnarchus* can sense the location of nearby objects without seeing them. In fact, this fish can tell the difference between living and nonliving things in its electric field. What advantages does an electric-perception system have for this fish? Do people have any kind of electric perception?



Analyzing data

1. What determines the information an animal can receive?
2. Why is it hard to imagine what a fish, bat, or moth perceives?
3. A scientist put a blindfolded rattlesnake in a cage that had a light bulb in the corner. When the light bulb went on, the snake attacked it. Why did this happen?

Investigation 3-2
How reliable are your senses?

In Investigation 3-1, you learned that different animals receive different information from their environments. A grasshopper, a bird, and a person may perceive the same meadow quite differently. Now consider another problem about perception. How good is the data we receive? Do our sense receptors tell us exactly what our environment is like? Do we all get the same data from our environment? This Investigation should help you answer some of these questions. Your group may do some or all of the parts, depending on the time and supplies that are available.

The ability to taste

Are any two people exactly alike? Do people have different perceptions of the same things? For example, some people like spinach. Some people do not. Perhaps people grow to like certain foods. Or perhaps people differ in their sense of taste. Try to find out if everyone in your class has the same ability to taste.

Materials
PTC paper

Gathering data

Chew the piece of paper long enough to decide what it tastes like. Observe your classmates while they are tasting the paper. Write down your own reactions and those of your classmates.

The nontasters may be puzzled at the strong reactions of some of their classmates.

Analyzing data

1. Did everyone in your class have a similar reaction to the paper?
2. How many people could taste the paper? How many people could not?
3. Could the tasters agree on a description of the taste?

The ability to see

Are you good at judging distances? How long is the room you are in? Can you tell by just looking? Can you guess how tall a person is without measuring his height? This activity will help you find out how good you are at judging distances.

Materials
tracing paper
cardboard or heavy paper
scissors
felt-tip marking pen
ruler

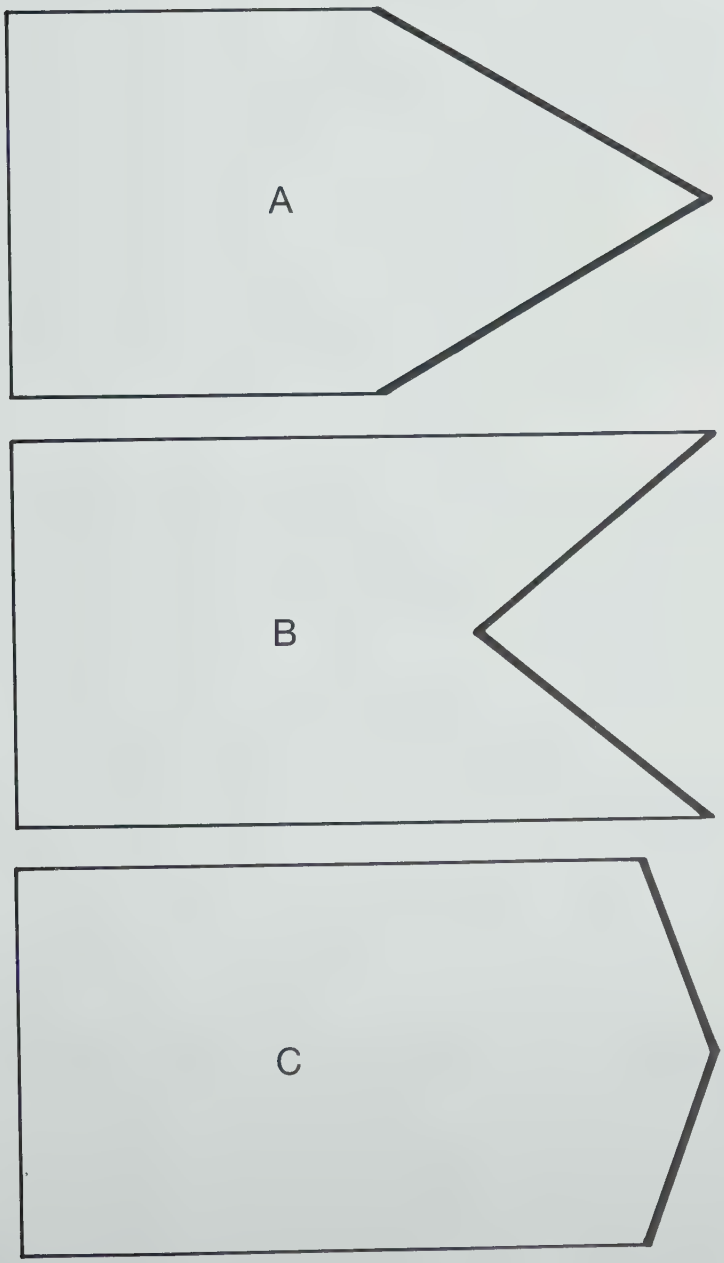
Gathering data

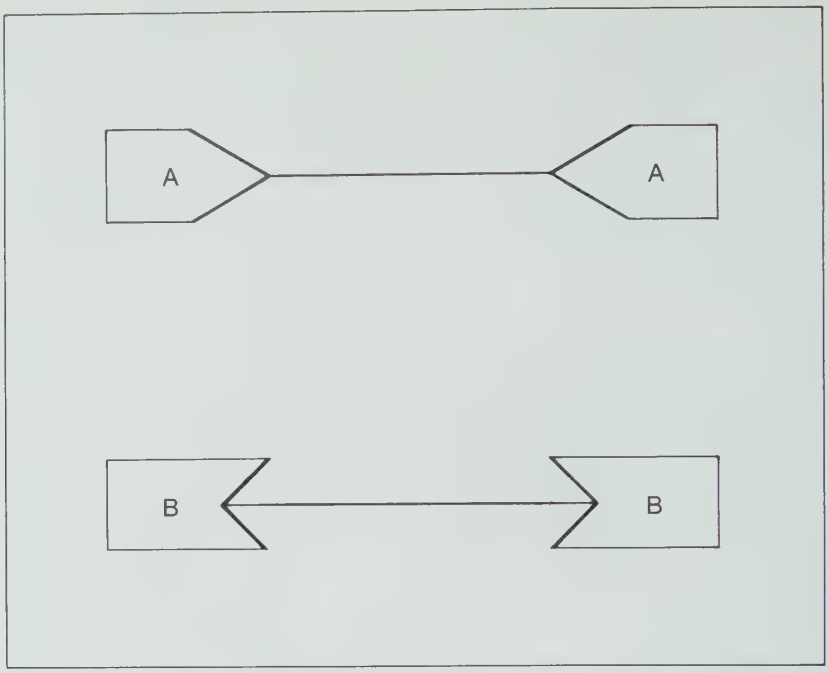
You will work in small groups during this activity. Each group will prepare its own materials. Trace Shapes A, B, and C, and use these tracings as patterns. Draw two outlines of each of the pieces on heavy paper or thin cardboard. Draw two thick lines on each piece to match the heavy lines on the patterns in the book. Label the pieces, and cut them out.

Make a group chart for recording data. Leave space to record three trials for each person in your group.

Person	*Trial*	*Distance*			
		A–A	*B–B*	*A–A*	*C–C*
Carla	*1*	–	–	–	–
	2	–	–	–	–
	3	–	–	–	–

To begin the activity, turn your book sideways and use the lines on page 37. Place the two A-pieces on the top line, any distance apart. Then place the two B-pieces on the bottom line.


A
B
C



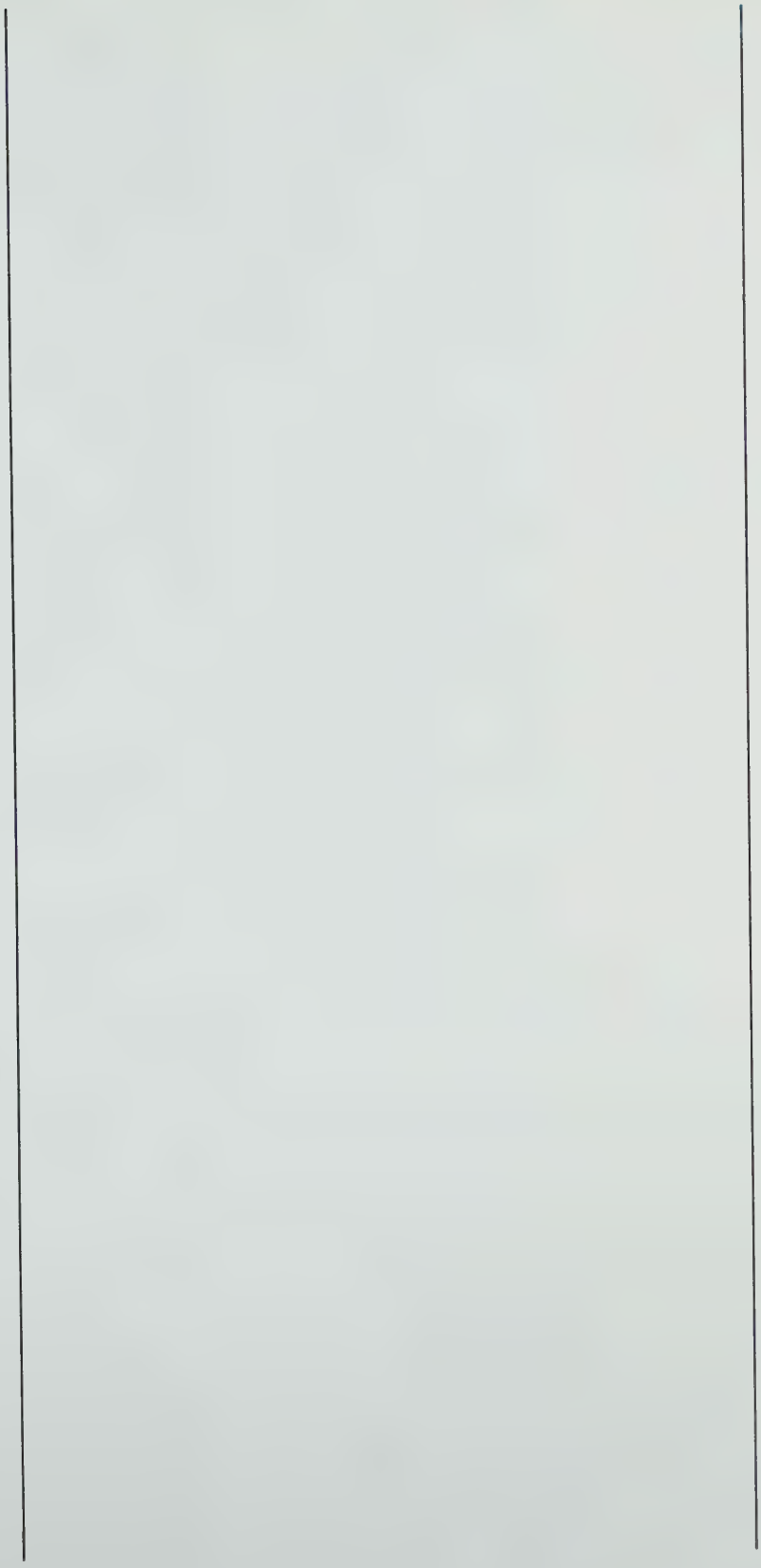
How to place the cutout shapes on the lines.

Move the B's until you think they are exactly as far apart on the line as the two A's. Have another member of your group measure and record the length of the line between the A's and the length of the line between the B's. Repeat this procedure two more times using a different distance between the A's each time.

When each person in the group has completed three trials, substitute the two C-pieces for the B's. Now test your ability to compare the distance between the A's and the C's. Record three trials for each person.

Analyzing data

1. Look at your data. How well do the A-A and the B-B distances match? How well do the A-A and the C-C distances match?
2. Do you think the shapes of the pieces had anything to do with the accuracy of your estimates? If so, why do you think this happens?
3. In your own words write the best explanation of the data.



Hot or cold

Did you ever hold your hand close to an iron to find out if the iron was hot? What you were doing was sensing the heat being given off. We all have sense receptors in our skin that detect heat. But how accurate are these receptors? Do they give us reliable information?

Materials
3 containers of water
thermometer

Gathering data

One hand will sense the water in Pan X as warm, the other as cool.

Your teacher will tell you how many students will do this activity. If you do this activity, first place one hand in Pan H and the other hand in Pan C. Then, after one minute, place both hands in Pan X. Tell the class what you feel. Is the water in Pan X hot or cold? Is the data you get from each hand the same? Now measure the temperature of the water in each pan with a thermometer.

Record your observations and your classmates' responses. Also record the measured temperatures of the pans of water.

Analyzing data

Suppose you had to describe to another person the water temperature of Pan X. Which data would you use and why?

Determining the direction of sound

Your left and right hands can be fooled about water temperature. A thermometer gives a more accurate temperature reading. How reliable are your ears? They are probably good at telling loud sounds from soft sounds. But with your eyes closed, can you tell the direction a sound is coming from?

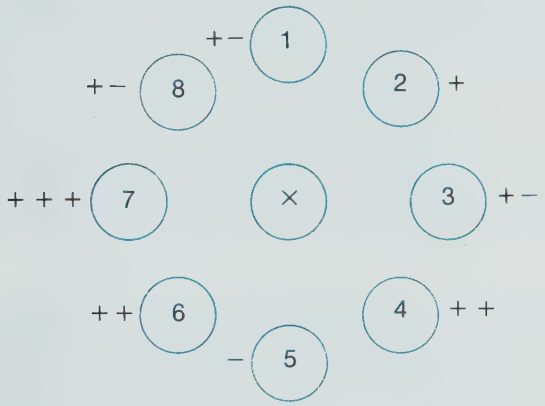
Materials
8 noisemakers
blindfold

Gathering data

Groups of nine students are needed for this activity. Eight students should form a circle and number themselves 1 to 8.

Each student has a noisemaker. The remaining student, the subject, is blindfolded. Make sure the blindfold does not cover the subject's ears. The subject sits in the center of the circle, facing Position 1. The subject should not turn his head during the activity. The person in Position 1 will select students to click their noisemakers. Choose another student to record the data.

To begin, the student in Position 1 points to another student who then clicks his noisemaker. The subject tries to point in the direction the sound came from. Wait until the data is recorded before choosing another noisemaker. Do not select noisemakers in order. Remember that the student in Position 1 can also take a turn.



Check the subject about 15 times. Each time the subject guesses correctly, place a **+** next to the number of the position on the chart. If the subject guesses incorrectly, place a **—** next to the number of the correct position. Test at least four or five different students. Make a new chart for each subject. Summarize the class data in a table. Count the number of **+**'s and **—**'s for each position and record the totals in your table.

Position	*Correct responses*	*Incorrect responses*
1	–	–
2	–	–
3	–	–
4	–	–
5	–	–
6	–	–
7	–	–
8	–	–

Analyzing data

Are the sounds from some directions perceived more accurately than those from others? If so, try to think of an explanation for the differences.





People use a parabolic microphone to pick up signals from different directions. A deer can do this by simply moving its ears.

Investigation 3-3
How does experience affect perception?

So far you have looked at the kinds of data animals get from their environment through their sense receptors. This data is only the raw material for perceptions. For example, your eyes notice only black marks on this page, but you perceive them as words. More than sense receptors are involved in perception. Do our past experiences affect the way we perceive the present? The next three activities will help you answer this question.

What don't you hear?

Gathering data

Can you remember all of the things you saw on the way to school this morning? Or all the sounds you heard? Do your ears pick up more noises than you are aware of? What factors affect what you hear and what you do not? Discuss these questions with your classmates. During the discussion your teacher will run a tape recorder.

After the discussion, your teacher will stop the recorder and replay the tape. Listen for sounds in the room you were not aware of during the discussion. What kinds of sound were there?

Place the tape recorder microphone where it is most likely to pick up sounds from outside the classroom.

Analyzing data

How do you decide what to listen to? What were some of the sounds you heard that your classmates did not hear? Why do you think you heard them?

You might want to investigate questions like these: Does your hearing affect your skill at ping-pong? Which is the noisiest room in your house? Does noise affect your ability to concentrate?

Encourage individual students or groups that wish to pursue these additional questions. Stress the importance of students initiating and following through on projects that interest them.

How do we perceive sizes?

Did you ever wonder why the people on your television screen seem to be life-size? Or why cars and houses seem so small when you look down from a tall building? This activity will help you answer these questions.

Materials
tracing paper
scissors
cardboard or heavy paper

Gathering data

Trace the outline of the car. Using your tracing as a pattern, cut two cars from heavy paper or cardboard. Place one of the cars over the letter "A" on the photograph. Place the other car over the "B." Which car seems bigger? Move the cars around on the picture. Do you always get the same effect? What clues help you perceive the size of objects?

There are many perspective clues: receding street, reduced size of faraway objects, and proximity to the horizon.

Does the building with the arch through it seem to be close or far away? Write down all the clues you can find in the photograph that help you determine the distance.

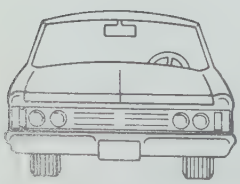
In this scene there are no size clues. Even the clothing on the person is deliberately vague so that a defensible judgment is impossible.

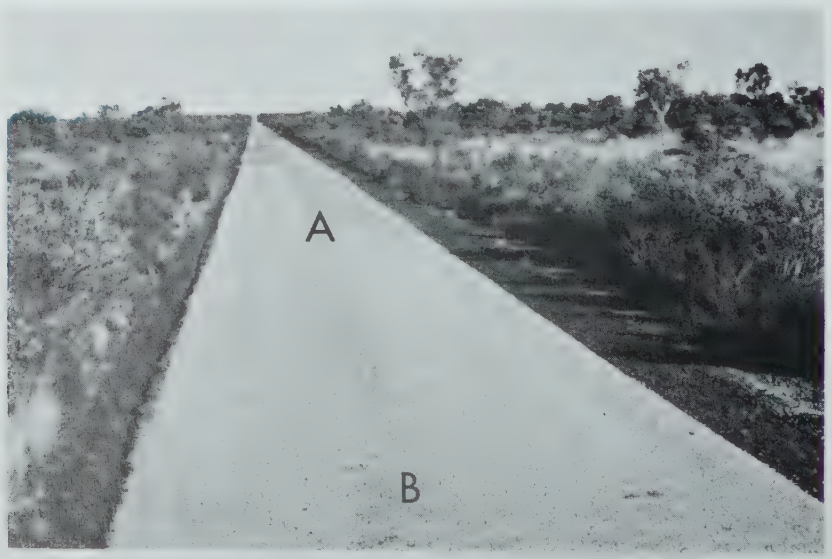
Is the person in the photograph at the bottom of page 43 an adult or a child? a male or a female? Give any data you can find to support your answers.

Analyzing data

1. Summarize the clues you used to determine the size and distance of objects.
2. How did you learn about these clues?
3. Would a small child know these same clues?
4. Bring in several pictures from magazines or newspapers that illustrate the clues you have learned.

Your students might want to show the car cutouts and the photograph of the road to younger children at home. They might see how young a person can be and still perceive the illusion.









Does everyone perceive in the same way?

Suppose you witnessed an automobile accident and had to answer questions about the event. Would your description of the accident be accurate? Would your description be complete? Would different witnesses give the same description?

Materials
4 pictures

Gathering data

In this activity you will be shown four pictures. Each picture will be projected for ten seconds. Write down what you see. The teacher will then show you each picture a second time. This time you can study it for several minutes and compare your perceptions with those of your classmates. Have one student record on the chalkboard what the class saw in each picture.

Analyzing data

1. The first time the pictures were shown, did everyone notice the same details?
2. After the second viewing, were you able to agree on the content? For instance, could you agree on the colors used and the objects or patterns shown?
3. After the second viewing, were you able to agree on the meaning of the pictures? For example, was the mood of the pictures sad or happy? What was the artist trying to say to the viewer?
4. What kinds of perceptions are people more likely to agree on? Is disagreeing about the meaning of a picture the same as disagreeing about the length of a line?

Extend Your View 3-1
Perceiving a city street

Find out if you have learned to infer how perceptions are related to sense receptors. This quotation describes the behavior of a 52-year-old man who regained his sight after being blind.

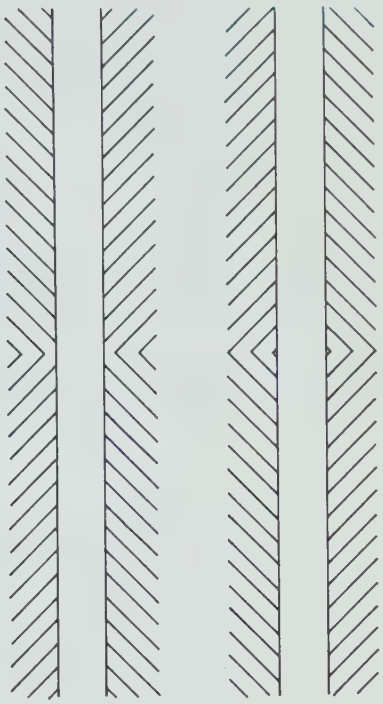
"Before getting back his sight, S. B. was unafraid of traffic. He would cross the street alone, holding his arm or cane stubbornly before him,

until the traffic would stop. . . . But after the operation, it took two of us, one on either side, to force him across a road. He was terrified as never before in his life." (Modified from Gregory, R.L. *The Eye and the Brain.* New York: McGraw-Hill Book Co., 1966.)

Why do you think this man's perception of the street changed?

Extend Your View 3-2
Another illusion?

How does past experience affect your perceptions? Can you use measurements to improve the accuracy of your perceptions? Use the drawing to answer these questions.



1. Do the pairs of vertical lines look straight?
2. Do you think that the lines are straight? Have you had any past experience that would influence your answer?
3. How could you find out if the lines are straight?

Extend Your View 3-3
A difference of opinion

How will different people perceive the same event? Suppose a car is weaving back and forth across the road. What inferences might these different people make? Why might their perceptions differ?

1. a police officer
2. an auto mechanic
3. a driving instructor
4. a doctor



4

Organizing data

After you complete these Investigations, you will be able to

1. identify which items fit a pattern that you perceive.
2. classify a collection of objects in more than one way.
3. decide if something is living or nonliving.
4. infer from its properties whether an organism is a plant or an animal.
5. organize quantitative data to answer a question.

Do you collect things? Perhaps you are interested in stamps, coins, shells, baseball cards, or records. Some people collect antiques, dolls, or cameras. Others even collect matchbook covers or sugar wrappers.

Once you have a collection, you can organize it. Stamp albums help organize a stamp collection. The stamps are usually organized by country. Or they can be grouped by subject. Shells might be harder to organize. They can be organized by color, size, shape, or where they were found. Record albums can be grouped by type of music, composer, or performer.

The telephone directory has peoples' names organized in alphabetical order. How are names, addresses, and phone numbers arranged in the classified "Yellow Pages" directory? Students can also be organized into groups. They can be placed into groups based on age, sex, musical interest, or athletic ability.

The classified directory is first organized by type of product, business, or service. Then the names in each category are alphabetized.

Grouping, or **classifying,** helps people organize things. People can manage a small number of groups better than a large number of separate things. Scientists often classify things for the same reason. In this Investigation, you will learn to classify and organize data in several ways.

Investigation 4-1
Perceiving a pattern

Which of these examples make sense to you? Try to find a pattern in each example.

1. Aaaaaa bb ccc dd eeeeeeeeeee fhhh ii llmm nnnnnn ooooo rrr sssssssss ttttttt uvwxy.
2. Above and as contains exactly letters numbers of same sentence the this those words.
3. This sentence contains exactly the same numbers of letters and words as those above.

Every language has ways of making sentences. Only Example 3 has meaning in English. The letters are in the right order to make words. And the words are in the right order to make a meaningful sentence. The other two examples have patterns, but the patterns do not make sense. In Example 1, the letters follow a pattern of alphabetical order. Example 2 has the same words as Example 3. But the words are in alphabetical order, not in a meaningful pattern.

Words are patterns that you have learned to recognize. In this Investigation, you will see what other kinds of pattern you can perceive.

Gathering data

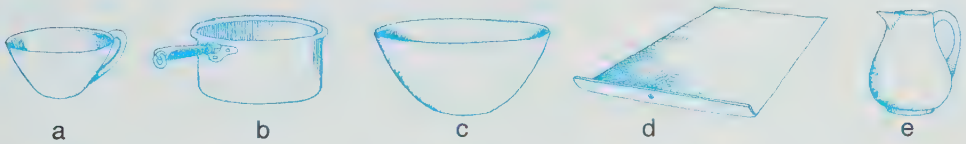
Look at these sets of drawings. Each numbered item has five choices. Four of each five follow a pattern. Number from 1 to 8 on a piece of paper. For each item, write down the letter of the object that does not fit the pattern. Also describe the pattern you perceived.

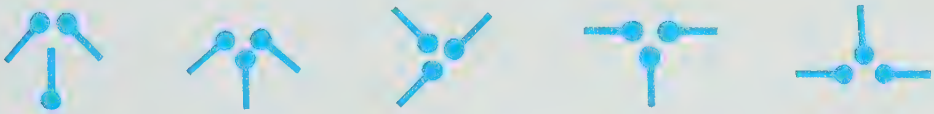
Analyzing data

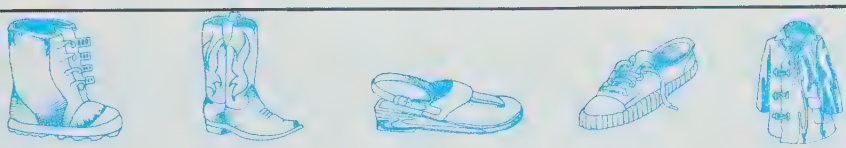
1. Did everyone perceive the same pattern for each item? If so, try to find other possible patterns. Is one perceived pattern better than another?
2. What properties of the figures did you consider as you tried to identify a pattern? How was perception involved in the identification?
3. What patterns can you find that would place two objects in one group and three in another?
4. Are there other possible patterns in these examples?

1 6 7 3 5 9
a b c d e

2 V C A M I
a b c d e

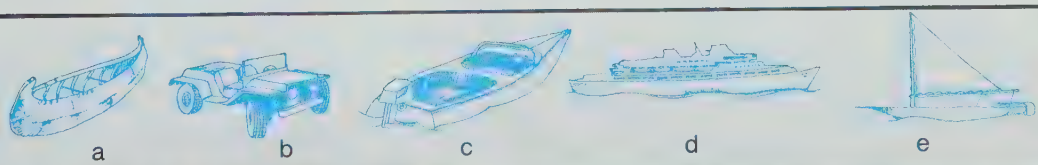
3 
a b c d e

4 
a b c d e

5 
a b c d e

6 
a b c d e

7 
a b c d e

8 
a b c d e

Investigation 4-2
Patterns help to organize

In this Investigation, you will observe properties of nonliving things. Then you will classify the objects according to the patterns you perceive.

Materials
several collections of nonliving things

Use real things for the grouping tasks. See Teacher's Manual for suggestions. Try to have enough collections so that each student can actually handle the things and move them into the groupings that he tries.

Gathering data

Look carefully at the collection that your teacher shows you. Divide the collection into two groups. Each group should share some property that the other group does not. Describe the property used to make the first grouping. Then list the objects that you place in each group. Put at least two items in each group.

Having at least two items in each group allows for subclassification

How could you classify these plants?



Once you have formed two groups, try to subdivide each group into two more groups, using another property. As before, you should have a reason for your grouping. And you should list the objects in each subgroup.

Now, put all the items back into one group. Repeat the process of grouping and subgrouping. But this time try using different properties. Remember that you can also use more than one sense. In the same way, classify as many other collections as you have time for.

Analyzing data

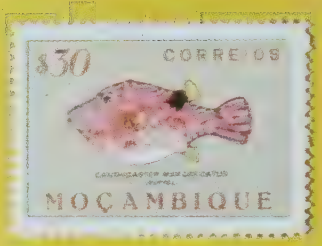
1. Compare your classifications with those of your classmates. Did everyone use the same properties for making groups?
2. How many possible ways are there to classify a collection of objects?
3. How many groups and subgroups can be made from one collection? What is the smallest number of items that can be in a group?
4. How is classification useful as one way to organize data?

How could you classify these items?



These artifacts can be classified by size, shape, or color. If the students know about these tools, they can also classify them by function.

























How many ways can you classify these stamps?


MAGYAR POSTA


日本郵便
15
NIPPON


REPUBLIQUE FEDERALE DU CAMEROUN
CERCOPITHEQUE MOUSTAC
POSTES


BUDAPESTI ÁLLATKERT
60
MAGYAR POSTA


CESKOSLOVENSKO
160 Kcs


30
MAGYAR POSTA


GR
30
CRYPTOCLEIDUS
POLSKA


1.00
REPUBLIK INDONESIA


REPOBLIKA MALAGASY
12f


25
AUSTRALIA


MAGYAR POSTA

Investigation 4-3
What does "alive" mean?

Molds, mushrooms, and yeasts are classified as plants by some scientists but as protists by most. "Protists" is a catchall label for organisms that have both plant and animal characteristics. Since this term will not be used later in the course, there is no need to introduce it.

What do a spider, a dandelion, a camel, and a human being have in common? How can you tell if something is really alive? First you must decide what properties living things share. In this Investigation, you will look at a number of different things. You will try to decide whether or not they are alive. You will also decide if they are plants or animals.

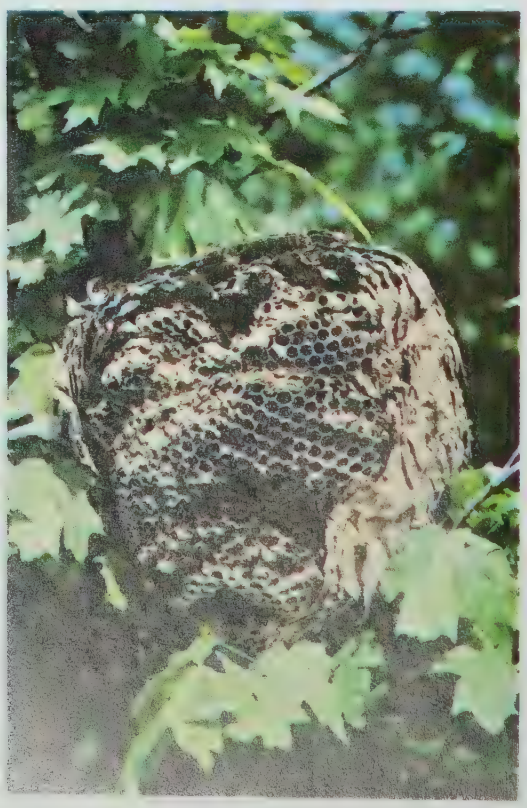
Gathering data

Look carefully at the items that your teacher shows you. Try to make lists of properties that separate living from nonliving things, and plants from animals.

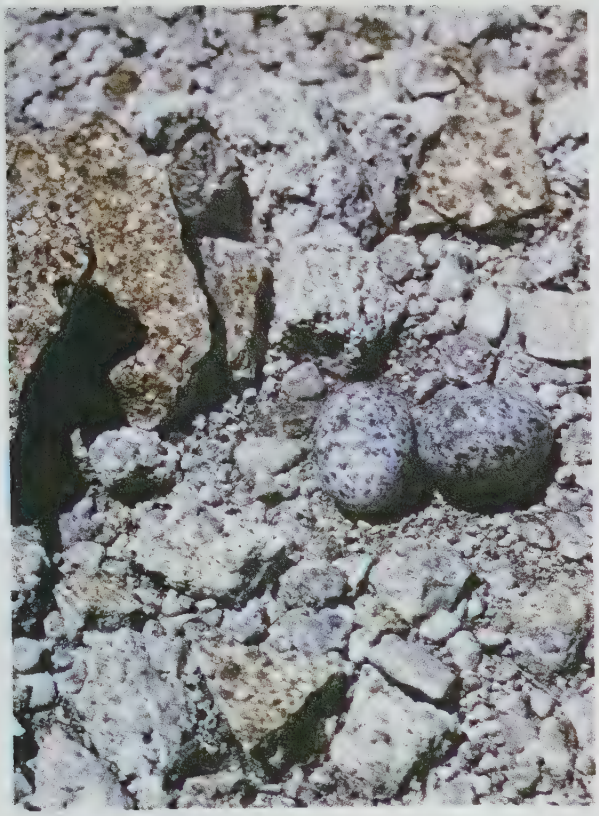
Analyzing data

Make three lists of properties on the chalkboard: one for plants only, one for animals only, and one for all living things.

Do you agree with all the properties the other students chose? Is there one property that can always be used to separate living from nonliving things? plants from animals?













Which of the objects on pages 54 and 55 are alive? Try to separate the plants from the animals.

page 54 (left) hornet's nest, (right) monarch chrysalis; page 55 (top left) nighthawk eggs, (top right) caterpillars, (lower left) spiddle-bugs, (lower right) rough green snake

Investigation 4-4
Organizing quantitative data

There are people who specialize in collecting data to answer questions. Television networks want to know how many people are watching which shows. Political candidates want to know voters' opinions on different issues. These people usually collect large amounts of data. The data must be organized before they can make inferences and answer their questions.

In this Investigation, you will have a similar problem. You will collect data on heartbeat rates. Then you will try to organize your data to make inferences.

Materials
clock or a watch with second hand
construction paper (optional)

Gathering data

If any students want to measure the pulse rate, discuss the way a pulse can be located. Pulse points are commonly found in the wrist, the temple, and the neck directly beneath the jawbone. The thumb contains a pulse that can sometimes be detected by pressing the thumb against the two adjacent fingers. When fingers are pressed against fingers on the other hand, no pulse is detected.

Choose a partner. Decide on a method to observe his or her heartbeat quantitatively. You may want to make a simple stethoscope (STEHTH uh skohp) by rolling a sheet of construction paper into a tube.



Make a table to organize your data. The exact form is not important, but the table should be easy to understand. Here are two ways you might arrange your data. Also describe your method for observing heartbeat. If you use more than one method, be sure to describe both of them.

Data table—Heartbeat

Method 1: count pulses in neck for 15 seconds
Subject: G.M.

Trial	*Pulses in 15 seconds*
1	*17*
2	*19*
3	*15*
–	–
–	–

Method 2: listen to heartbeat with stethoscope and count beats for 30 seconds
Subject: G.M.

Trial	*Beats in 30 seconds*
1	*35*
2	*33*
–	–
–	–

Whatever method you use, repeat it several times. Try to keep all conditions the same from one observation to the next. Do you think changes in room temperature, noises, and your own movement might change the heartbeat rate? You can probably think of other conditions that should be kept the same. After you have observed your partner's heartbeat, have him observe yours.

Analyzing data

1. Did everyone in your class report the same heartbeat rate?
2. Suppose you counted your partner's pulse for 15 seconds, and another classmate counted pulses for 30 seconds. What would you have to do before you could compare the two sets of data?
3. Can you compare observations made by different methods?
4. What is the range of the data? Where in the range is your heartbeat rate? Is it fast, slow, or in between? Is the range the same for the girls and for the boys?
5. Calculate the average heartbeat rate for the whole class, for just the girls, and for just the boys. How do the averages compare?

The heartbeat rate would be affected by the general health of the student, the amount of exertion immediately preceding the class, and any stimulation (physical or emotional) during the activity.

Graphing is another way to organize this kind of data. A bar graph is a useful kind of graph for organizing heartbeat data. To make a bar graph, first organize your data into groups as shown in the table on page 58.

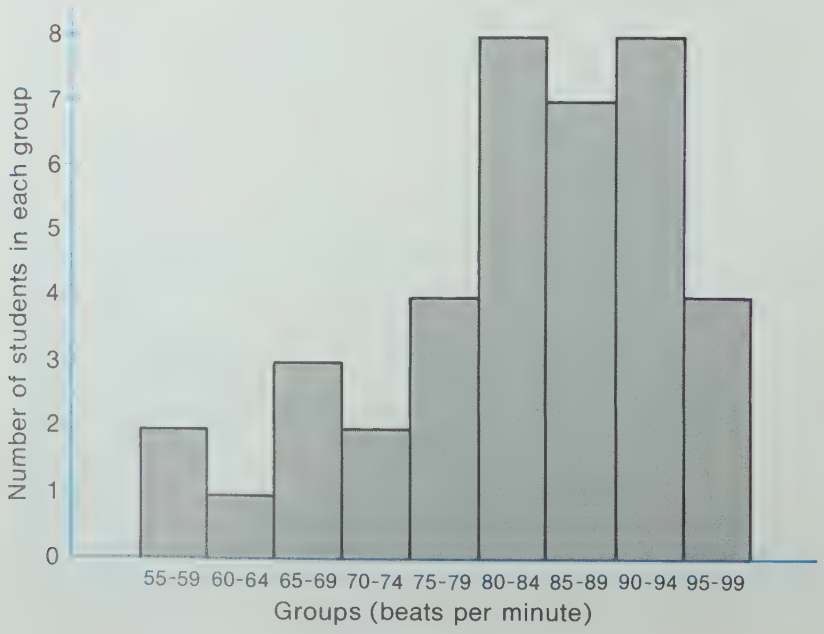
Groups (beats per minute)	*Number of students in each group (Tally)*	*(Total)*
55–59	||	*2*
60–64	|	*1*
65–69	|||	*3*
70–74	||	*2*
75–79	||||	*4*
80–84	𝍸 |||	*8*
85–89	𝍸 ||	*7*
90–94	𝍸 |||	*8*
95–99	||||	*4*

Notice that each group covers a range of five heartbeat rates. You can choose any range for your groups. Just make sure it is the same for each group. Tally the number of students whose heartbeat rates fall into each group.

Look at the bar graph that was made from the data in the sample table. Notice that the groups go on the horizontal axis. The vertical axis shows the number of people in each group. The more people in a group, the higher the bar on the graph.

The first bar graph could be done by the entire class, especially if the students are not familiar with graphing. If they catch on quickly, have them do the other graphs in small groups.

Make a bar graph for the data on your whole class. Make two other bar graphs for the separate data on the girls and the boys. What do the bar graphs tell you about heartbeat rates for your class? How do the bar graphs for girls and boys compare?



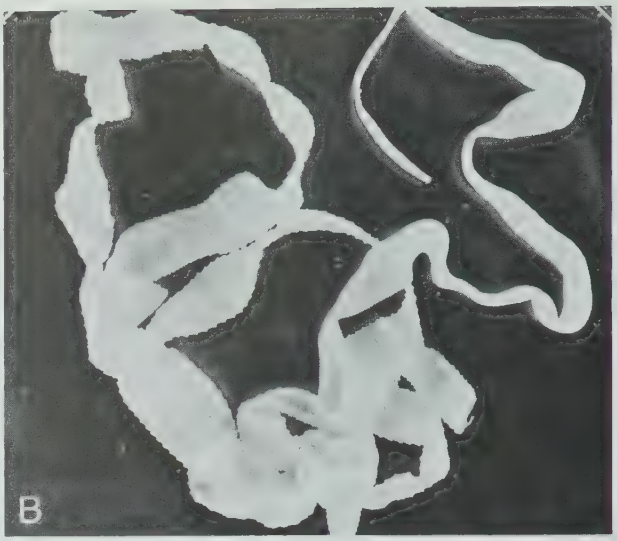


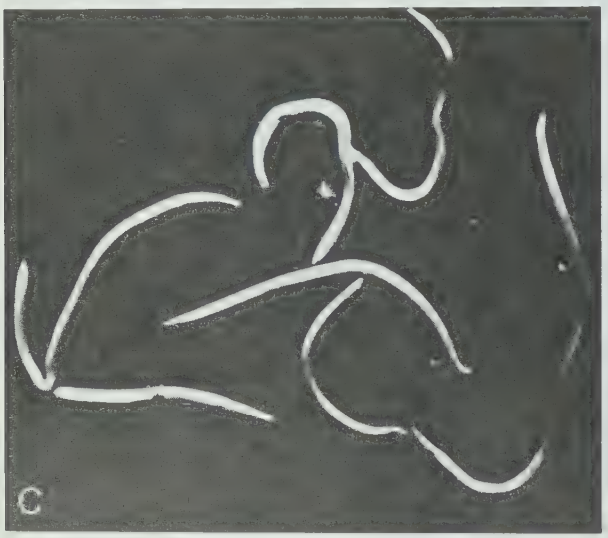
Try to classify these birds into groups that eat the same food.

The students must go beyond simple grouping here. The organisms are all birds, but from bill structure and other physical properties it is possible to infer which ones may have similar diets.

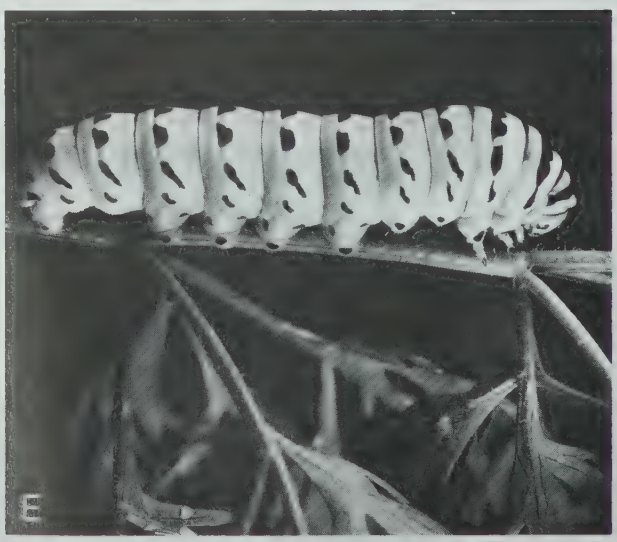
These groups probably have similar diets: ah, bd, eg, fi. You might also include c with fi. It would probably be incorrect to put a and h together with e and g. All four are water birds, but their bills have different shapes.


A


B


C


D


E

Extend Your View 4-1
Which one fits a pattern?

Can you identify which items fit a pattern that you perceive? Find a pattern that places four organisms in one group and one by itself. Which item on page 60 does not fit the pattern? Then identify a second pattern that places three organisms in one group and two in another.

Extend Your View 4-2
How can you classify these students?

Can you classify the same collection in more than one way? Find at least four different ways to classify these students into two distinct groups. If you knew the students in the photograph, what other properties besides physical appearance could you use to classify them?



Extend Your View 4-3
Dead or alive?

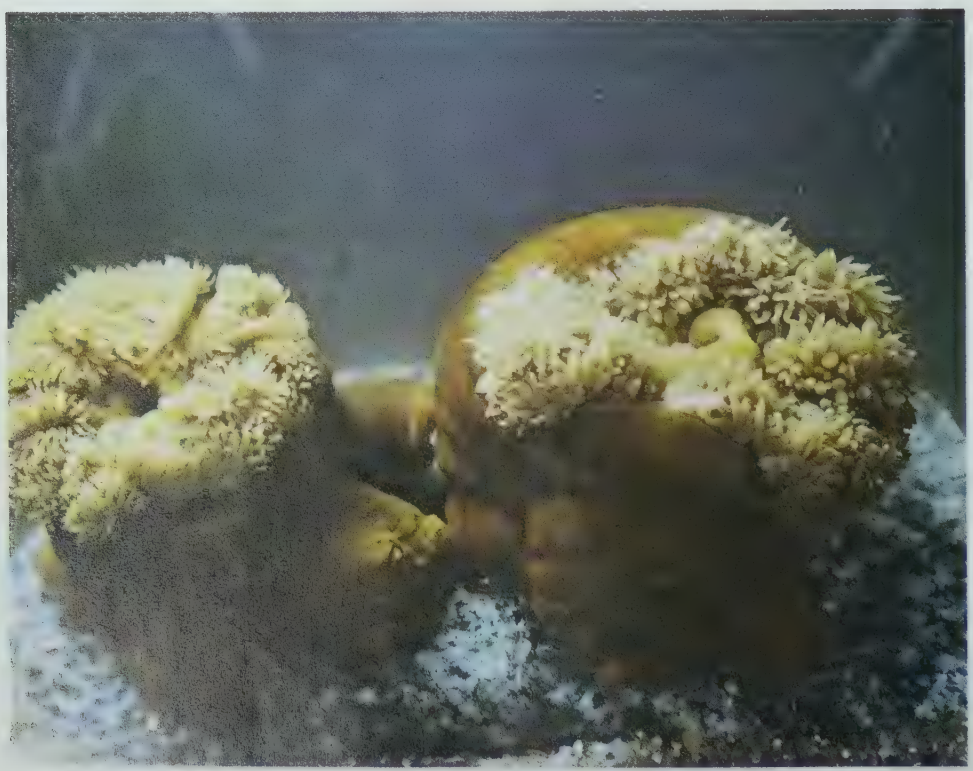
Can you decide if something is living or nonliving? When should a person be classified as dead? In 1968, in Virginia, a 56-year-old man received serious head injuries in an automobile accident. The man was no longer breathing when he reached the hospital. He was put on a machine that breathed for him. Because his brain was no longer working, the doctors said that the man was dead. But his heart was still beating. They transplanted his heart into another patient.

The electroencephalogram showed no brain waves.

The victim's brother sued the doctors who did the operation. He said his brother was still alive when the heart was removed. If you were on the jury at the trial, how would you have voted? Do you think the man was dead when his heart was removed?

Extend Your View 4-4
Plant or animal?

Can you infer from its properties if an organism is a plant or an animal? This organism lives in shallow seas. Is it a plant or an animal? What clues can you get from the photograph? List the reasons for your choice.



Extend Your View 4-5
Holding your breath

Can you organize quantitative data to answer a question? Use the data in Table 4-1. Are boys or girls able to hold their breath longer? How did you organize your data to answer the question?

Encourage the students to make bar graphs from the data, as well as calculating the range and average.

Table 4-1 *Time that breath was held*

Name	Time (seconds)	Sex
Bruce	74	M
Ed	48	M
Ann	55	F
Ralph	69	M
Fred	69	M
Annette	53	F
Barbara	60	F
Jane	51	F
Maureen	77	F
Bob	69	M
Dennis	61	M
Gary	47	M
Sylvia	86	F
Joyce	41	F
George	47	M
Doris	62	F
Paula	61	F
Shawn	49	M
Steven	67	M
Douglas	39	M
Ernie	44	M
Audrey	82	F
Don	84	M
Amanda	56	F
Paul	68	M
Dolores	58	F
Maria	52	F
Eric	76	M
Nancy	55	F
Manuel	49	M
Gretchen	55	F
Janet	56	F


RCA
TS100

5

Making and testing hypotheses

After you complete these Investigations, you will be able to

1. select properties that can be used as variables.
2. make a hypothesis about two variables.
3. organize data to decide if a hypothesis is supported or rejected.

Suppose you have a homework assignment due the next day. There is also a movie on television that you've been waiting all week to see. Can you do your homework and also watch the movie?

When you make any decision, you have to consider a number of factors. A factor that can change or have a number of different values is called a **variable.** In this situation, the amount of homework and the time it will take to do it are both variables. If your homework takes only 30 minutes, you can probably watch the movie. What if your homework takes two hours? Even "the results of not doing your homework" is a variable. These factors would all vary from day to day.

The student's bedtime could also be an important variable.

Many of the properties that you have been measuring are variables. The heights and weights of your classmates vary. So do their heartbeat rates and their ability to hold their breath. So far you have looked at each variable separately. In these Investigations, you will look for connections between variables.

Investigation 5-1
What is a hypothesis?

Suppose your school has a basketball team that won only two of its last ten games. Very few people go to the games and there are no cheerleaders. Perhaps the lack of student interest has affected the team's performance. There are two variables in this situation: the number of games won and the number of spectators. You might guess that the two variables are related. A reasonable guess about the connection between two variables is called a **hypothesis** (hy PAHTH uh sihs). There is often more than one possible hypothesis in a situation. For example, the team could be losing because the players do not practice. Or perhaps the players are shorter than the players on other teams.

Hypotheses need not be expressed in *if-then* terms. If students understand the concept of relating two variables, and are more comfortable with an alternate form, do not insist on adherence to the *if-then* form.

It is useful to first change a hypothesis into a form that is easier to test. The three hypotheses about the basketball team could be written:

1. *If* the number of spectators increases, *then* the team will win.
2. *If* the players practice more, *then* the team will win.
3. *If* the coach gets taller players, *then* the team will win.

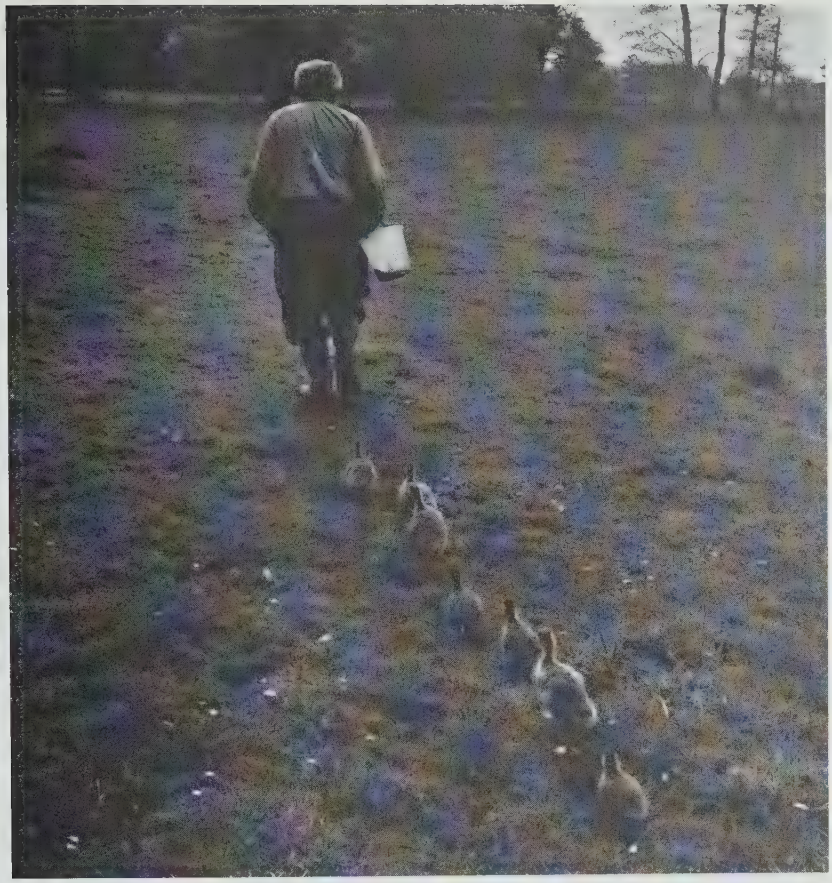
When you put a hypothesis in the *if . . . then* form, you are making a prediction. You are predicting that changing the *if-variable* will also change the *then-variable.* To see if your prediction is correct, you have to test your hypothesis. You can practice making and testing hypotheses using the heartbeat data from Investigation 4-4.

Materials
data from Investigation 4-4
graph paper
instruments to measure variables related to heartbeat

Gathering data

To help the students choose variables, have the five students with the slowest heartbeat rates go to one side of the room, and the five with the fastest rates to the other side. Ask the students if there are any obvious properties that each set of people share.

Look at your data from Investigation 4-4. Think of a variable that might be related to the heartbeat rate. Make a hypothesis using heartbeat rate as your *then-variable.* You may need to collect data for the *if-variable* you have chosen. Suppose your *if-variable* is height. You will have to measure the height in centimetres of each person in the class. You would make a list of names, heartbeat rates, and heights.



Make a hypothesis to explain each observation on pages 67 and 68.

These animals follow this person around.



People in this hot, dry region wear heavy, loose clothing.



This young person is skilled enough to play with a symphony orchestra.

There were no mushrooms at this spot the day before this photograph was taken.



Analyzing data

There is no one way for you to analyze your data. You want to pick the simplest way that will reveal a pattern if one exists. You already know several ways to organize your heartbeat data. If your *if-variable* were height, you could arrange the class in order from the shortest to the tallest. Then you could divide the class into two groups: the taller half and the shorter half. You could compare the average heartbeat rate for each group.

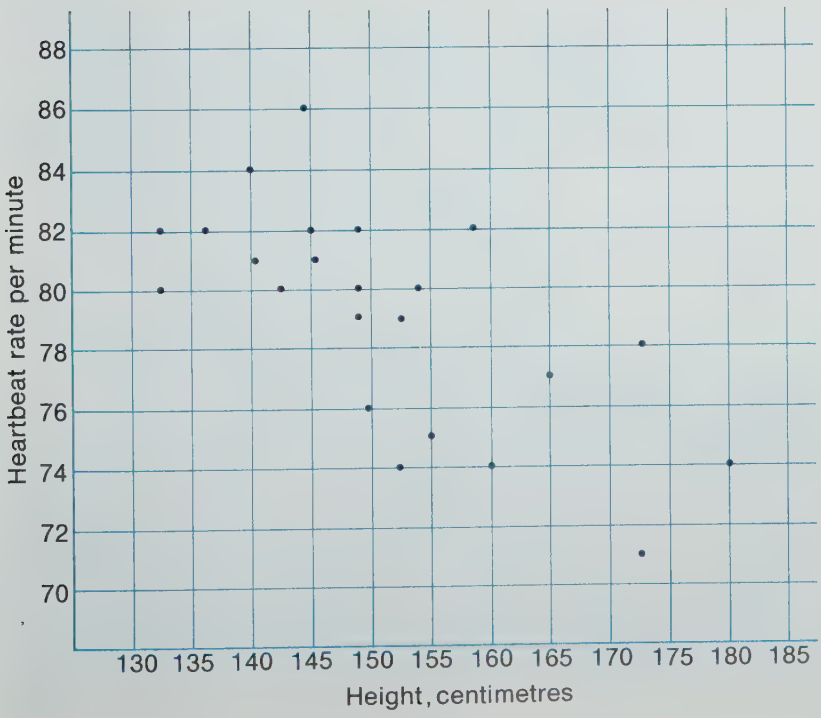
Data can be pooled in a grid ruled on the chalkboard or a transparency for overhead projection. Students can work in small groups or individually to analyze the data.

You can also use graphing to analyze your data. (If you do not know how to make a graph or want some review, read Appendix C.) This graph was made to test the hypothesis: If a student is taller, his heartbeat rate is faster. Does the graph show that taller students have faster heartbeat rates? If the graph does show this pattern, you can say "The data supports the hypothesis." Suppose the graph shows just the opposite pattern. You would have to reject the original hypothesis. Sometimes there is no pattern in your data. You cannot say that the data supports your hypothesis. But neither should you reject the hypothesis without additional data.

The graphing program in Appendix C is designed so that a student can complete it in 15–20 minutes.

Even if the data supports a hypothesis, you cannot say, "The hypothesis is true." You can only say, "The data supports the hypothesis." New data that contradicts the hypothesis may turn

This scattergram would seem to indicate that taller people tend to have slower heartbeat rates. However, one cannot generalize on the basis of such a small sample. Neither can one generalize from a group to the individual, or from one group to an entirely different group.



A broad generalization should be based on data from a large number of subjects chosen at random from the general population. The class will tend to be a rather homogeneous group that does not represent a sampling of the general population. In this case, a more specific conclusion is better: in a group of 28 students, ages 11 to 13, the taller ones tend to have slower heartbeat rates.

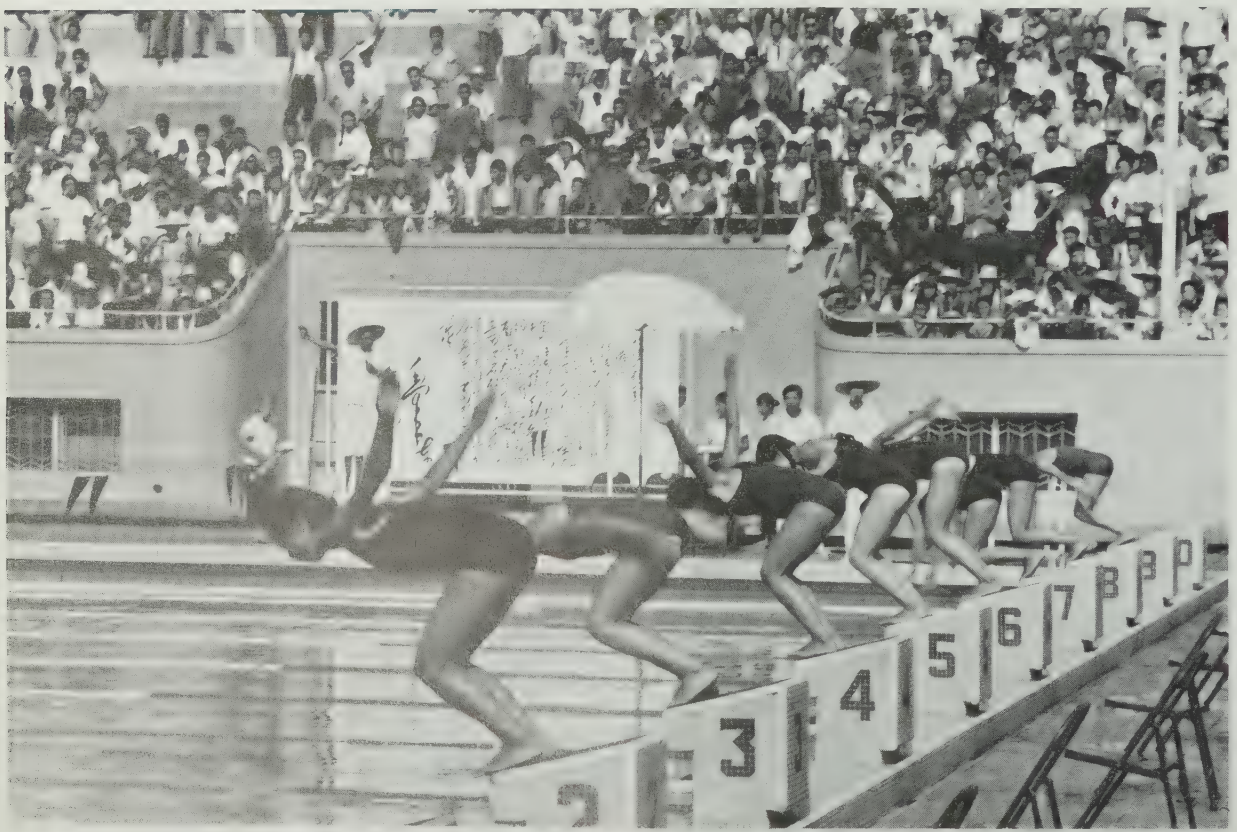
up later. There is also another danger—the danger of over-generalization. You cannot say what is true for your class is true for people in general.

Investigation 5-2
Testing another hypothesis

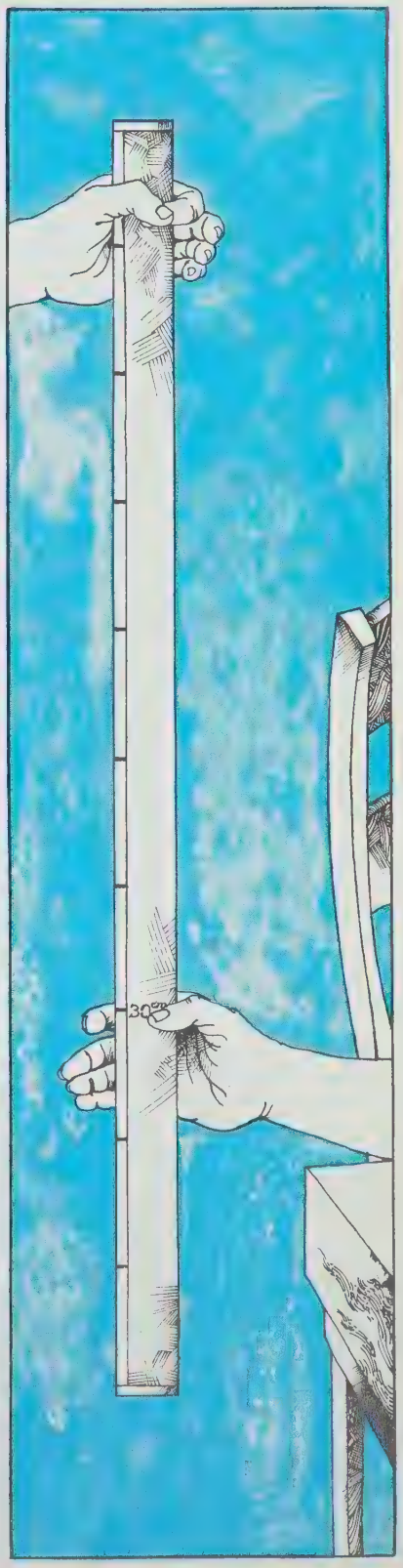
You can introduce this activity by using a brand new dollar bill or a piece of stiff paper cut the same size. Select half a dozen students to try to catch the bill when it is dropped. If a student's forearm is on a table or desk as described, it is almost impossible for him to catch the bill.

How fast a person responds to a signal is called **reaction time.** A quarterback's reaction time may make the difference between an incomplete or a complete pass. A bike rider's reaction time may make the difference between an accident and a near-miss. Do athletes have faster reaction times than spectators? Can reaction time be improved by practice? This Investigation may help you answer these questions.

A fast reaction time could help a swimmer win a race.



Materials
metrestick
other measuring instruments



Gathering data

Make a hypothesis about reaction time and another variable. Reaction time will be the *then-variable.* Collect data to test the hypothesis. You may be able to use some data from earlier Investigations, for example, the data on height or handspans from Investigation 2-4.

Here is one way to measure reaction time. You will work in pairs. Have one student hold his arm as though he were going to shake hands. Have him support his forearm on a table or a desk. Make sure his fingers extend beyond the edge. The distance between his thumb and index finger should be about two centimetres.

Stand facing your partner. Hold the 100-cm end of the metrestick between your thumb and index finger. Place the metrestick between your partner's thumb and index finger. Your partner's index finger should be at the 30-cm mark. Be sure your partner is not touching the metrestick.

Have your partner watch the 30-cm mark. As soon as the metrestick begins to drop, he will try to catch it between his thumb and index finger. Let the metrestick hang motionless, and then release it without warning. You may have to practice this a few times.

The distance the metrestick drops depends on your partner's reaction time. The shorter the distance, the faster the reaction time. How many centimetres does the stick drop before your partner catches it? Remember that you started at the 30-cm mark. Test your partner several times. Record each measurement. Then trade places and have your partner measure your reaction time.

Analyzing data

Did the metrestick drop exactly the same distance each time you made a measurement? If not, you need to take the average of your trials. You may also want to find the range of the class data. Does your data support your hypothesis?

1. Did your reaction time improve with each trial?
2. Do people with fast reaction times share some characteristics in common? Are they more athletic? Are they older than your other classmates?

The students may want to investigate these questions. It is likely that reaction times will vary especially when the students switch hands.

3. Would you have the same reaction time if you tried the test with your other hand?
4. Would you have a different reaction time early in the morning or late at night?

Extend Your View 5-1
Heartbeat rates for different animals

Can you select properties to use as variables? Can you make a hypothesis about two variables? Look at the data in this table. These measurements came from average adult animals at rest. List at least three properties of the animals that might be related to heartbeat rate. Write at least two hypotheses using the properties you have chosen as the *if-variables.*

Table 5-1 *Average heartbeat rates*

Animal	Heartbeat rate (beats per minute)
cat	180
cow	50
dog	100
goat	85
hamster	347
horse	45
monkey	220
mouse	610
pig	70
porpoise	75
squirrel	390
whale	15

Extend Your View 5-2
Who can run 50 metres fastest?

Are you able to organize data to decide if a hypothesis is supported or rejected? Use the data in the table to test these five hypotheses:

1. Boys run faster than girls.
2. Older people run faster than younger people.

3. Brown-eyed people run faster than blue-eyed people.
4. People with greater mass run faster than those with less mass.
5. Taller people run faster than shorter people.

Copy each hypothesis on a separate sheet of paper. Mark each hypothesis either:
S = supported by the available data
R = rejected because the data shows the opposite
N = neither supported nor rejected

Table 5-2 *Data gathered on 50-metre runners*

Subject	Eye color	Sex	Age (years)	Height (centimetres)	Mass (kilograms)	Time (seconds)
1	blue	M	12	165	50	6.3
2	blue	F	13	140	45	6.5
3	brown	F	13	163	41	6.0
4	blue	M	13	152	57	7.4
5	blue	M	12	155	54	7.1
6	brown	F	11	152	58	7.8
7	brown	M	11	157	50	7.3
8	brown	F	12	155	41	7.2
9	brown	F	11	142	48	7.5
10	brown	M	12	168	45	6.2
11	blue	F	12	156	41	7.0
12	brown	M	13	165	39	6.3


Cleveland
C.R.L
BU
PHOTO

6

Doing experiments

After you complete these Investigations, you will be able to

1. describe the difference between a poorly-designed experiment and a better one.
2. use what you learn about respiration to predict the results of an experiment.

Breathing is something you do all the time. When you breathe, you take air into your lungs and then let it out. But the air you take in is not the same as the air you let out.

Most of air is a gas called nitrogen, a gas that your body does not use. The part of air that your body needs is a gas called oxygen. The oxygen you breathe helps release the energy that is stored in food. The food and oxygen both change.

Not all the oxygen (O_2) that is inhaled is used; exhaled air also contains oxygen.

$$\text{food} + \text{oxygen} \xrightarrow{\text{change into}} \text{energy} + \begin{matrix}\text{carbon} \\ \text{dioxide}\end{matrix} + \begin{matrix}\text{other} \\ \text{products}\end{matrix}$$

This process is called **respiration.** Your body does not use the new gas, carbon dioxide, and you breathe it out. When you breathe you exchange gases with your environment.

Carbon dioxide (CO_2) that is produced is used by the body to help regulate the breathing rate. The students need not be concerned about this distinction.

Do all living things exchange gases with their environment? You can observe people breathing, but what about other living things? How can you tell if an organism is giving off or using up a gas? In these Investigations, you will experiment to answer some of these questions.

Investigation 6-1
Do aquatic plants and animals exchange gases?

It is difficult to tell if an organism is using oxygen. It is easier to tell if an organism, especially an **aquatic** (uh KWAHD ihk) one, is giving off carbon dioxide. Aquatic organisms live in the water. In your experiment, you will try to detect carbon dioxide. If you detect it, you can infer that the organism is using oxygen.

Simply supply the materials and suggest where to put the tubes. For the tubes that require light, the lights should be continuous and moderately strong, but avoid overheating the organisms. The organisms will not be overheated if the students use a cooler fluorescent light.



Materials
blue liquid
soda straw
3 test tubes
3 stoppers
test tube rack
test tube holder
burner
aquatic plant
2 snails

Gathering data

The blue liquid you will use in your experiment contains water and a chemical. If you add carbon dioxide to the liquid, the chemical changes color. Test the blue liquid before you do the experiment. Fill a test tube one-third full with the liquid. Breathe out through the straw into the blue liquid. What happens to the blue color? Did everyone get similar results?

Place your thumb firmly over the mouth of the test tube and shake the tube. Make the liquid mix with the air. Watch for color changes. Can you shake the carbon dioxide out of the water? Carefully boil the liquid over an open flame for about one minute. Slant the test tube and make sure the open end is not pointed toward anyone. Do you see any color changes now? Does boiling remove the carbon dioxide? Now you can investigate the question, "Do snails and aquatic plants take in oxygen and give off carbon dioxide?"

Your group will prepare three test tubes. Fill all three tubes almost to the top with blue liquid. Leave room for a large piece of a plant in Tube A and two snails in Tube B. Make sure the stoppers are tightly sealed. Label your tubes A, B, and C. Label your test tube rack with the initials of the people in your group.

Half the groups should place their set of tubes under lights but not in direct sunlight. The rest of the groups should place

their set in a dark place, such as a closet. Leave the tubes undisturbed overnight.

Each tube should test a hypothesis about gas exchange. For example, one tube might test the hypothesis: If aquatic plants produce carbon dioxide in the light, then the blue liquid will turn yellow. Make a table in your notebook and write in the hypothesis you think each tube will test.



	Tube	*Hypothesis*	*Color*
Light	*A*	*If aquatic plants produce carbon dioxide in the light, then the blue liquid will turn yellow.*	–
	B	–	–
	C	–	–
Dark	*A*	–	–
	B	–	–
	C	–	–

On the second day, examine your test tubes. Record the color of each tube. Does the plant look different since the beginning of the experiment? Complete your table by exchanging data with the groups that tested different hypotheses.

Analyzing data

1. Which of your hypotheses were supported? Which were rejected?
2. If an organism produces carbon dioxide, you can infer that it is using oxygen. Did the snails and plants use oxygen when they were in the light? when they were in the dark?
3. What did you learn from Tube C? What if the blue liquid in Tube C had turned yellow?

Discuss the exchange of gases between plants and animals but avoid any detailed discussion of photosynthesis until Unit Two.

Can you be certain that it was the carbon dioxide from the plants and snails that caused the color change? Could variables such as temperature or humidity have caused the color change? In an experiment you try to test only one variable at a time. This kind of experiment is called a **controlled experiment.** In a controlled experiment all of the variables are kept the same except the one you want to test.

In this experiment, you were testing the effect of light on gas exchange. It was necessary to keep other variables the same. But it is difficult to match the conditions in a dark closet to the conditions in another part of the classroom. That is why you used Tube C. If the color change had been caused by a different variable, such as temperature, Tube C would have changed color too.

Investigation 6-2
Measuring respiration

This apparatus is called a respirometer.

It is sufficient for the students to understand the function of the CO_2 absorbent in the apparatus. They need not understand the mechanism. Actually the sodium hydroxide reacts with the carbon dioxide to form sodium carbonate and water.

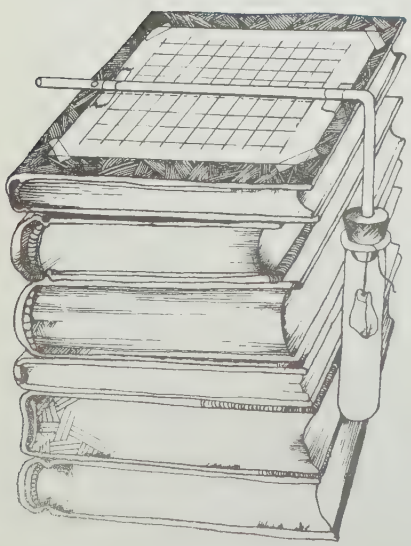
The carbon dioxide absorbent is a strong, caustic base. Students should not handle it. If the packet becomes very moist, some of the material could get on a student or an experimental animal. If this happens, flush the affected area with a solution of vinegar and water.

This setup can be used to measure the rate of respiration for a small organism. Remember that during respiration an organism uses up oxygen and gives off carbon dioxide. The pellets in the test tube can absorb carbon dioxide. So, as the organism uses up oxygen, the amount of gas in the test tube is reduced.

At the beginning of the experiment, the air pressure inside the test tube is the same as the outside air pressure. The pressure is the same on both sides of the liquid in the glass tube, the "L-tube." When the amount of gas in the test tube is reduced, the pressure inside the test tube is also reduced. The liquid in the L-tube is pushed toward the test tube by outside air pressure. The more oxygen is used up, the farther the liquid moves in the L-tube.

Materials

test tube
L-tube and rubber stopper
colored liquid
graph paper
tape
packet of pellets
books
living organisms
petroleum jelly



Gathering data

Your group should decide what your experiment will be. Your teacher has some organisms you can use in this Investigation. You can use the setup and live organisms to answer questions like these:

1. How far will six mealworms make the liquid move in five minutes?

2. Does one kind of insect use oxygen faster than another?
3. Do seeds use oxygen?

Choose one of these questions to investigate or think of one yourself. Write down your question and check with your teacher before you begin.

What variable will you be testing in this experiment? How can you be sure that a change in the movement of colored liquid is due to the test organism and not some other variable? Your group should decide how to control your experiment.

Ask the students to devise a control for themselves. If they have trouble, suggest one of the examples discussed in the Teacher's Manual.

Now put together the setup on page 78. The books will keep the L-tube level. Tape a piece of graph paper to the top book. Then tape the L-tube to the graph paper.

Place the organism in the test tube. You may have to use more than one organism if they are small. Put the packet of pellets into the tube so that the organisms cannot reach it. Firmly

Does a 125-g frog use 5 times as much oxygen as a 25-g frog?



place the stopper with the L-tube into the test tube. Make sure the string from the packet is between the stopper and the test tube.

Caution: The packet contains a dangerous chemical. If the packet opens and some of the chemical gets on you or the experimental animal, wash it off with a lot of water.

Wait five to ten minutes for the pellets to absorb the carbon dioxide in the container. Then put a drop of the colored liquid onto the end of the L-tube. The liquid should begin to move. If it does not, then your setup may be leaking. It may help to push the stopper more firmly into the test tube. Or try putting some petroleum jelly around the stopper.

Mark the starting point of the bubble of colored liquid on the graph paper. The graph paper will help you measure how fast the bubble moves.

Make several observations for each experiment. You can record the movement every 30 seconds, every minute, or every 5 minutes. It depends on how rapidly the liquid is moving. Put a mark on the graph paper at the end of each time interval. Later you will be able to count the squares to find out how fast the liquid moved.

Clean the L-tube after each use. Otherwise the dried food coloring will cause the bubble to stick on the next trial. Rinse the tube with water, then with acetone.

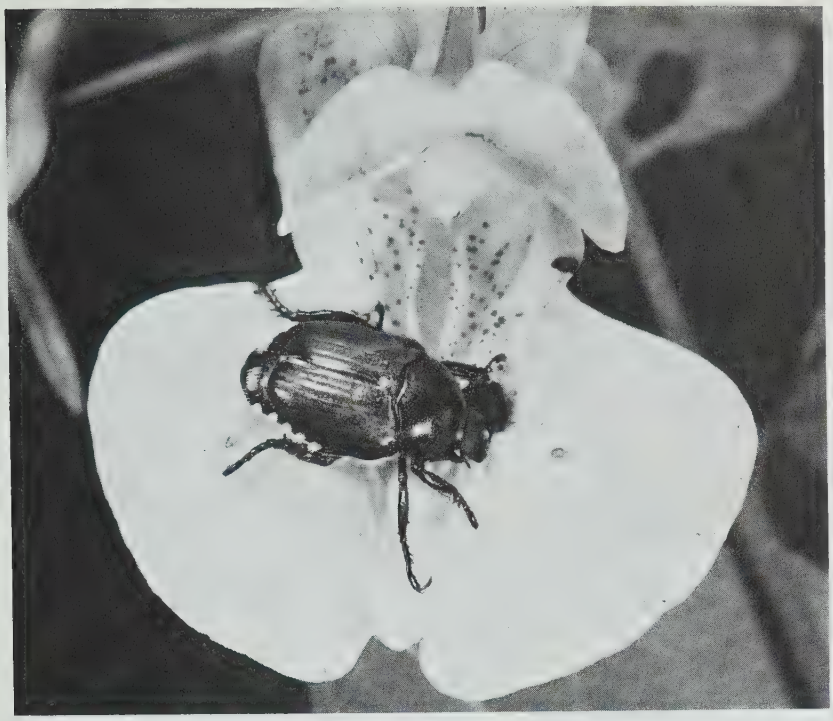
If you have time, it is a good idea to repeat the experiment to be sure of your results. Loosen the stopper between experiments. This gives the organism a fresh supply of air.

Make other observations you think are important. For example, does your organism remain still or is it very active? Keep accurate records of your data. A table is a good way to record your data. Write a brief report that shows how your data answers the question you are investigating.

Analyzing data

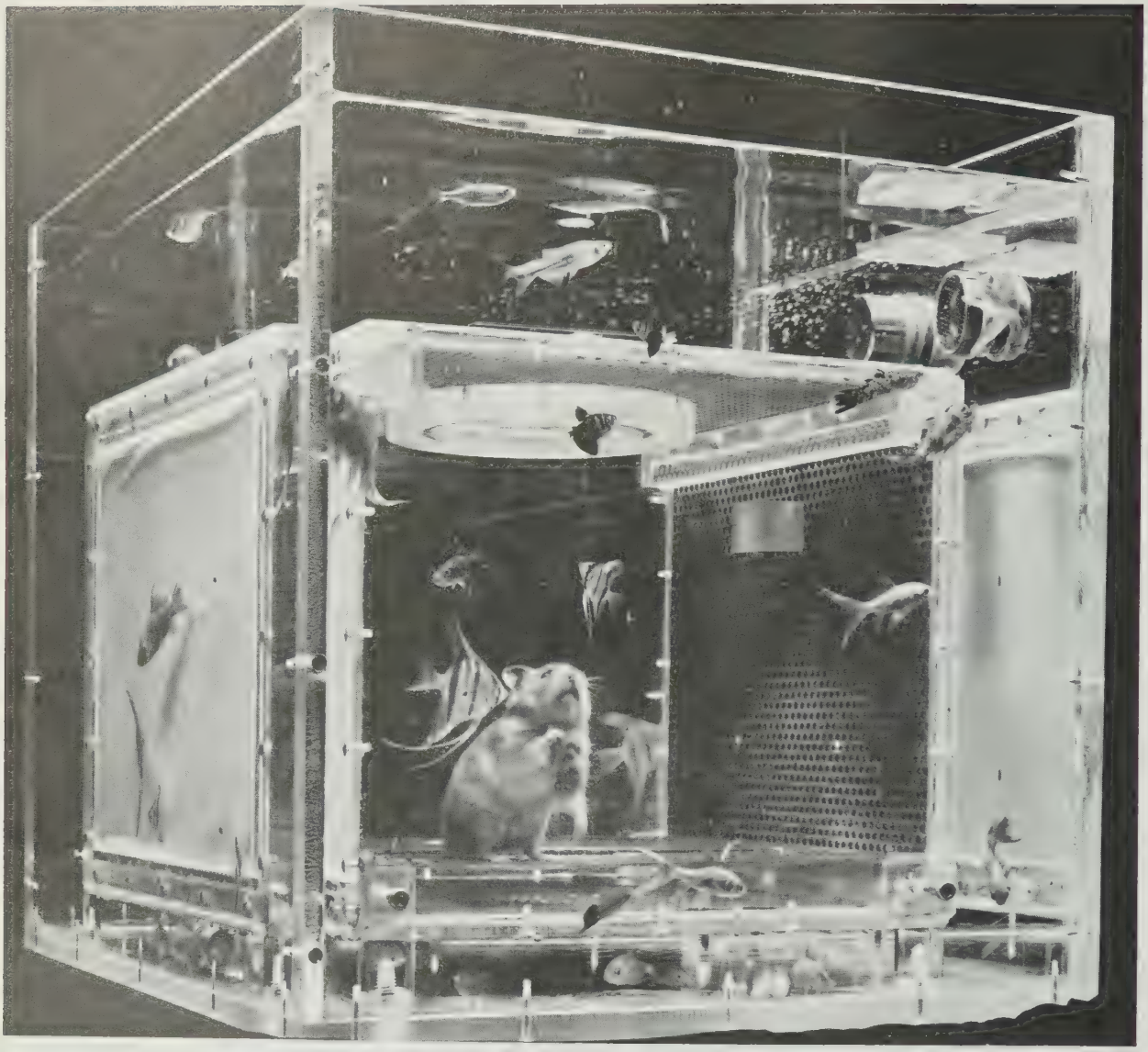
Encourage students to formulate additional questions about the experiment. You could ask, "Do you think that the time of day affected the results? How could you find out? What about the temperature or the type of light?" If possible, allow students to investigate new problems that they identify.
Do not tell students that data gathered without adequate controls is unreliable. Instead, ask questions such as "How do you know what would have happened without the organisms?" Then ask, "If you could repeat the experiment, how would you change the design to overcome this problem?"

1. The movement of the bubble showed that respiration was taking place. How fast did your bubble move?
2. Discuss your experiment and your data with your classmates. Compare your rate with data from other experiments. Can you make any general statements about gas exchange in living things?
3. Did active animals use more oxygen than ones that remained still?
4. Do seeds use oxygen? Can you think of a way to find out how fast one seed uses oxygen?
5. Can you think of better ways to control the experiment?



How do each of these organisms respire?





It appears that the hamster is breathing in the water. But the hamster is actually breathing oxygen that diffuses through a membrane that covers four sides of its container. Carbon dioxide diffuses out but water cannot pass through.

Hamsters and fish do not normally live in the same environment. Make a hypothesis to explain this photograph.

Extend Your View 6-1
Do roots use oxygen?

Have you learned to tell a poorly-designed experiment from a better one? Look at these two experiments. Two students hypothesized that if the roots of plants are given oxygen, the



roots will grow. To test the hypothesis, each student grew tomato plants in jars of water. They added chemicals for healthy plant growth.

The first student bubbled oxygen for two weeks through the water her plants were growing in. The second student bubbled oxygen through a jar with half her plants in it. The other half were in a second jar. No oxygen was bubbled through the second jar. Each student was careful to give the plants equal amounts of light. All the plants in both experiments lived and grew. Whose experiment would you consider a better test of the hypothesis?

Extend Your View 6-2
Survival

Use what you have learned about respiration to predict the results of this experiment. Two test tubes were filled almost to the top with the blue liquid you used in Investigation 6-1. An aquatic plant and two snails were added to each test tube. Tube A was left under a lamp overnight. Tube B was left in a closet overnight. Try to predict what color you would see in each tube on the second day. Give reasons for your predictions.



7

Designing experiments

After you complete this Investigation, you will be able to

1. design an experiment to collect data to test a hypothesis.
2. use a checklist to evaluate the design of an experiment.

Mike was given a goldfish for his birthday. One cold winter day he put the goldfish bowl on a table in front of a sunny window. That afternoon he sat down to watch his fish. He noticed that it was swimming actively. When he took a closer look at the goldfish, he also saw that the gill covers were moving rapidly.

Mike knew that fish breathe by taking gulps of water that contain dissolved oxygen. When the fish closes its mouth, its gill covers open. The water is forced over the gills where oxygen is exchanged for carbon dioxide. The drawing on the next page shows the direction the water flows. The faster the gill covers move, the faster the fish is breathing.

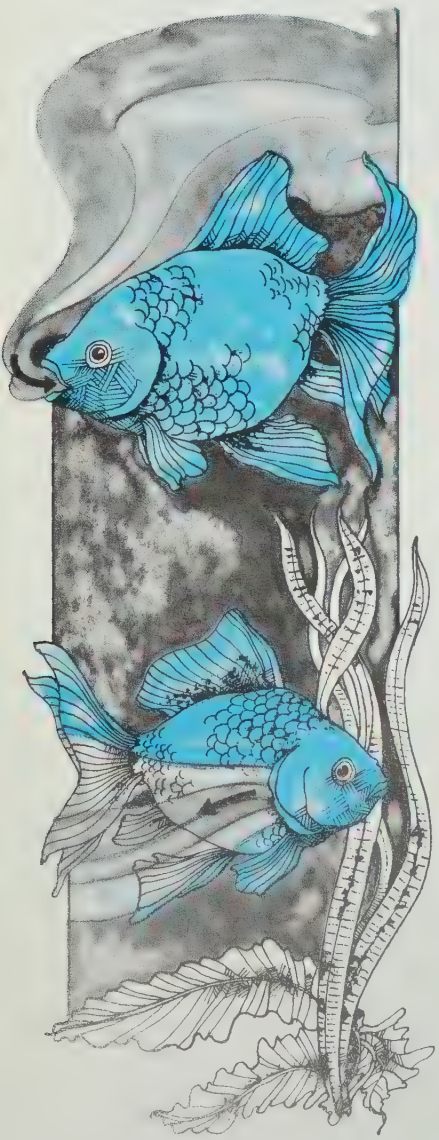
The next morning, Mike got up early. It was just getting light outside. He went to the window to look at his fish. It still looked the same, except that its gill covers now were moving very slowly. What do you think caused the breathing rate of the goldfish to change?

The story hints at two possibilities: light intensity and water temperature. Inventive students may suggest other variables not mentioned in the story, such as the fish's activity or hunger. The story itself does not provide enough information to confirm any hypothesis.

Investigation 7-1
The goldfish puzzle

The gill-cover beat is analogous to the rhythmic movement of the rib cage of terrestrial animals.

Some students may find it easier to count "mouth beats" rather than "gill-cover beats." A larger, less active fish will probably give more accurate counts.



Your teacher will give you a live goldfish to observe. How big is your goldfish? Does it move around or stay in one spot most of the time? Watch the movement or "beats" of its gill covers. Count the number of beats per minute. You will have to work with a partner, one counting the beats and one watching the clock. How could the size and activity of your goldfish make it hard to get an accurate count?

What variables might cause a fish's breathing rate to change? When you have a hypothesis that you want to test, answer Questions 1 and 2 in the *Checklist for designing an experiment* (bottom of this page).

Work in small groups to design an experiment to test your hypothesis. Plan ahead before you start. Your teacher will tell you how much time you will have and what equipment is available. Try to design an experiment so that all other variables are controlled except the one you are testing. Consider these questions when you design your experiment.

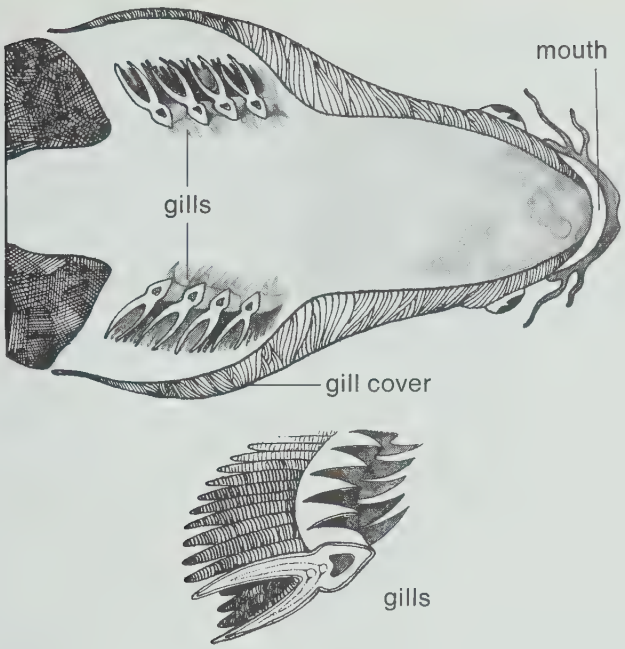
1. How long will you count the gill-cover beats each time?
2. How many times should you make counts?
3. How long should you wait between counts?
4. How much should you change the *if-variable* between counts?

When you think you have a well-designed experiment, answer Questions 3–8 in the *Checklist.* Then discuss your plans with your teacher.

Checklist for designing an experiment

In a well-designed experiment, these questions should get a "Yes" answer.

1. Have you identified your *if-variable?*
2. Have you identified your *then-variable?*
3. Have you identified other variables that may affect your experiment?
4. Does your experiment control these other variables?
5. Do you have a detailed plan of how to do your experiment?
6. Can you get the materials you will need for your experiment?
7. Can you get quantitative data from your experiment?
8. Have you planned a way to record your data?
9. Did you organize your data so you could analyze it?
10. Did you decide if your data supports your hypothesis?
11. Can you think of ways to improve your experiment?
12. Did you record any new questions that you thought of while doing this experiment?



Materials

Your teacher will help you get the materials you will need for your experiment.

Gathering data

Have you thought about the safety of your goldfish during the experiment? Be careful when you add anything to the fish's bowl and when you transfer the fish to a different bowl. To a fish there is a lot of difference between fresh tap water, distilled water, and the water it has been living in for a few days. Any sudden change might harm the fish. Make sure all changes are made gradually.

As you gather data, record any observations you make of the fish's behavior. Record anything that might affect your results. If you are not sure that some of your data is accurate, repeat parts of your experiment. If you repeat a well-designed experiment, you will get just about the same data.

Goldfish adapt well between 2° and 32°C. Warn students to stay within these limits to prevent damage to the fish.

Explain to all groups the difference between fresh tap water, water that has sat in a container overnight (becomes dechlorinated), distilled water (less minerals than tap water) and boiled water (contains less dissolved gases), and the possibility that the fish is sensitive to these differences. The type of water definitely should be a controlled variable.

Analyzing data

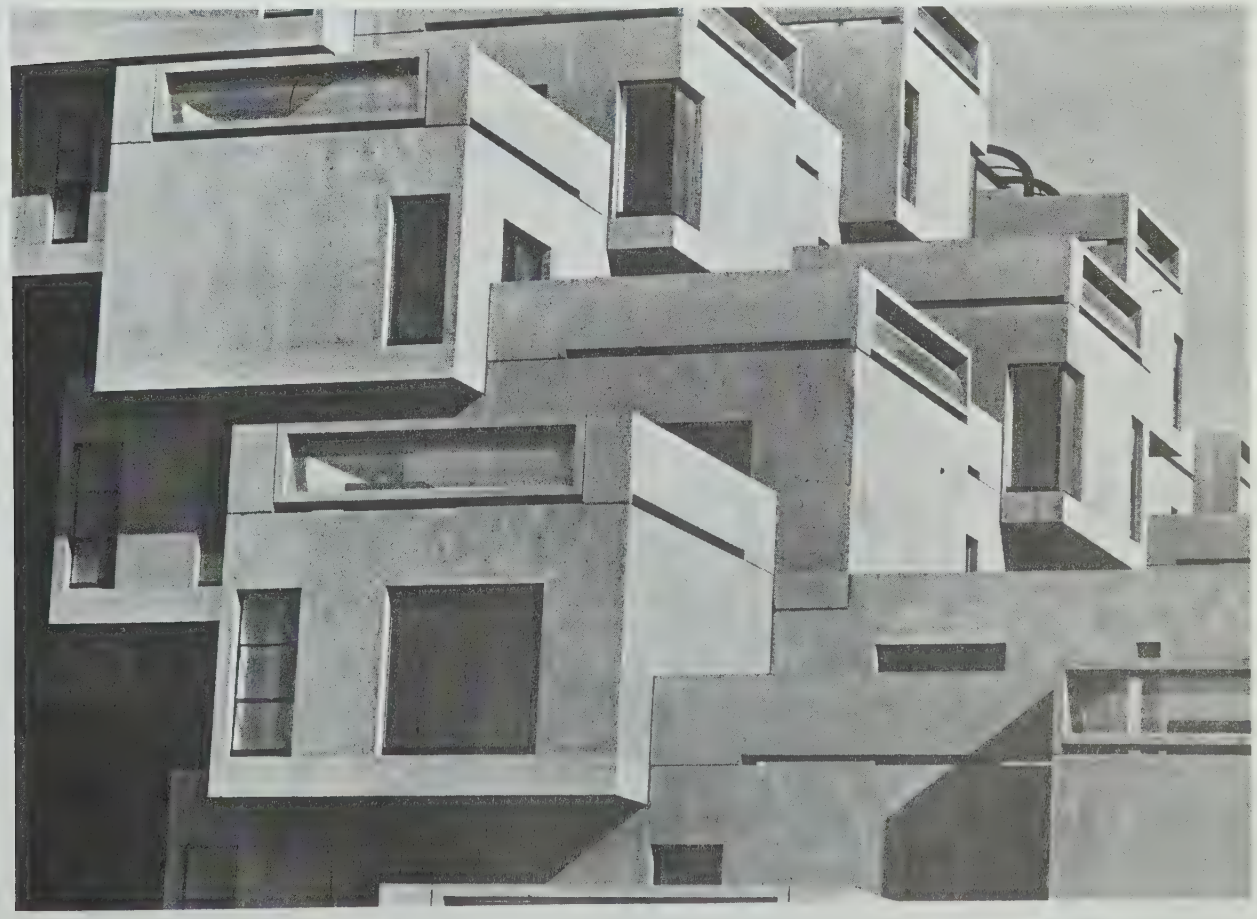
1. Organize your data in a way that will help you to analyze it. Can you make a graph from your data? What variables would go on the horizontal and vertical axes?
2. Decide if your data supports your hypothesis. If your data does not support your hypothesis, what else have you learned from your experiment?
3. Answer Questions 9–12 in the *Checklist*.

What hypothesis might have been the basis for each of these designs?






GREENWICH



Extend Your View 7-1
Does the size of a fish affect its breathing rate?

Did you learn how to design an experiment to collect data to test a hypothesis? Suppose your hypothesis is: The bigger a fish, the slower its breathing rate. Write a description of everything you would do to test this hypothesis. You do not have to actually do the experiment. Use the *Checklist* to help you.

Extend Your View 7-2
An experiment on breathing rates

Have you learned to use the *Checklist* to evaluate the design of an experiment? Maria wanted to test the hypothesis that a goldfish has a slower breathing rate than a Siamese fighting fish. She took a goldfish and a Siamese fighting fish from her class aquarium. She put each into identical bowls with tap water that had been sitting overnight.



Both bowls were put on a table two metres from the window. After each fish was put into its bowl, it was given its normal food. The gill-cover beats of each fish were measured for one minute. The goldfish had a rate of 5 beats more per minute than the Siamese fighting fish. Maria decided to accept her hypothesis.

Do you think she designed a useful experiment? In what ways could her experiment be improved? Did she consider all items on the *Checklist?*



8

Learning

After you complete these Investigations, you will be able to

1. identify changes in behavior that could be used to measure learning.
2. design an experiment to measure changes in behavior.
3. interpret a learning-graph.

The only way of knowing that a person has learned something is for the person to show it. For instance, just telling someone that you had learned to ride a bicycle might not convince him. But riding past him would show that you had learned.

Emphasize that learning may be inferred by observing an animal's behavior.

Suppose Anne made 2 out of 20 basketball shots. Would you say that she had learned to shoot baskets? Your answer is probably both "Yes" and "No." You might say that she had learned a little, but not much. There was still room for improvement or more learning.

Imagine that a month later you saw Anne make 10 out of 20 shots. You might infer that during the month she learned something. Or maybe she was just lucky this time. But if she could make 10 out of 20 shots a second time, you would probably think that it was more than luck.

You can design experiments to study learning. One problem is to decide what kind of learning to study. Activities such as learning to play basketball are difficult to study because they are complicated. It is easier to study simple types of learning that have fewer variables to control. And this is what you will do in these Investigations.

Examples of learning in basketball: learning to follow a trajectory with your eyes, to dribble, and to throw the ball into the basket (physical coordination); learning the rules and plays (memory); learning when to pass and when to shoot (strategy).

Investigation 8-1
Maze-learning

In this Investigation, you will study maze-learning. A **maze** is a set of pathways that leads to an end point. Many different animals, including humans, can learn mazes. When an animal travels in a maze, it must choose which way to turn to reach the end.

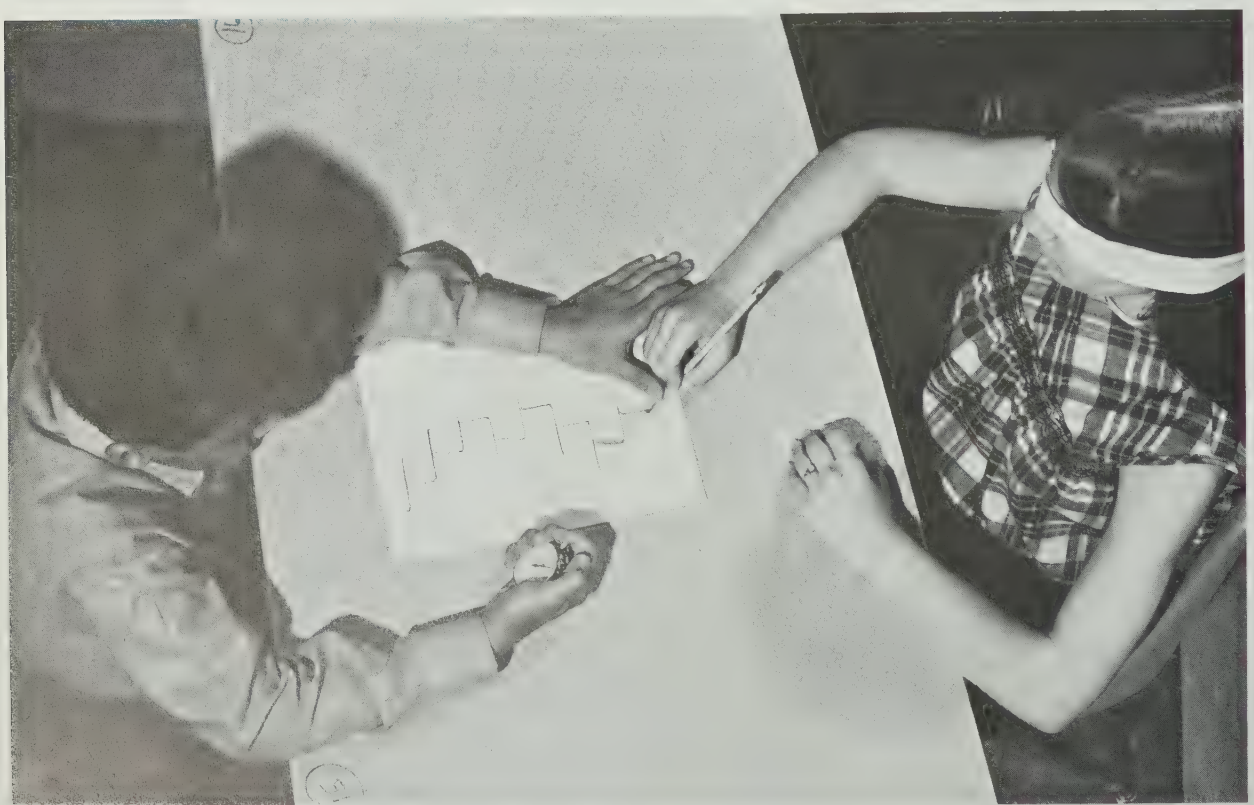
Materials
T-maze
stopwatch, clock, or a watch with a second hand
blindfold

Most students will have some familiarity with mazes. Identify the entrance and exit of the maze and its basic T-construction.

Ask the students what kind of results they might expect when a human or other animal is put in a maze. What will happen the second time? the tenth time? Students' hypotheses should provide a natural springboard to their maze-learning experiment.

Gathering data

Choose a partner. One of you will be the subject. The other will observe and record the data. If there is time, you can trade places after the first set of data is collected and repeat the experiment.



Blindfold the subject and have him or her sit at a desk. The subject should not see the maze during the experiment. Put the maze in front of the subject and hold the maze so it does not slide around. Place the subject's pencil or finger at the starting point.

When you are ready to start timing, tell the subject to "Start" through the maze. When the subject reaches the end of the maze, say "Stop." Write down the time it takes.

Return the subject's pencil or finger to the starting point. The subject should do at least six trials. Ten trials would be better. Do not tell the subject how much time each trial takes.

Record the number of each trial and the time the subject takes to go through the maze. Note also if anything unusual happens during a trial, for example, "Subject sneezed," or "Subject's pencil slipped out of maze and had to be put back in." If you trade places with the subject and repeat the experiment, you should use a different maze.

Familiarity with the maze will prejudice the results of the learning experiment.

What hypothesis are you testing? What is the *if-variable?* What is the *then-variable?* Make a graph from your data.

Analyzing data

1. What evidence is there that the subject learned during the experiment?
2. How did the subject learn to do the maze?
3. What would you predict the subject's time would be on a 20th trial?
4. What would the graph look like if the subject had learned the maze more slowly? more rapidly?
5. How might the learning-graph look if you repeated the experiment with the same maze and subject tomorrow? How might the graph look if you repeated the experiment with a different maze?

If someone asks if anything learned in the maze will be remembered, you may want to test this hypothesis with another day's experimentation. The procedure could be planned by the class.

The class might also be interested in discussing these questions: "What, if any, differences might you expect between your learning-graphs and those of fourth graders? between yours and your parents?" (Data could easily be gathered to answer these questions.)

Investigation 8-2
The mouse in the maze

Suppose you wanted to study the ability of rodents to learn a maze. You would have to design and construct a maze. Then you would have to buy some mice or gerbils or hamsters. They would need food and shelter while you were working with them.



rat

mouse





hamster

You might have to spend a few weeks running experiments. How would you make the animal want to run the maze? What would you do with the animals when you were through? This project would take time, money, and space. It is probably not practical for your class to do such an experiment.

Instead you will use data that has already been collected. The data is stored on a special set of cards. You will still have to ask your own questions. But you will not do an actual experiment to test your hypotheses. Instead you will use the cards to get realistic experimental data. This imitation of a real-life situation is called a **simulation** (sihmyuh LAY shuhn).

You may know about some simulations. A flight simulator helps pilots learn to fly. The simulator looks like the cockpit of an airplane. It has a full set of controls that are connected to a computer. The student-pilot operates the controls. The computer makes the instruments act like the instruments in a real airplane. The flight simulator does not fly, but it responds realistically to the way the pilot moves the controls.

Some driver-training classes also use simulators. This helps students learn to drive without the danger of hurting themselves, other people, or other cars.

Adjust the group size to fit the number of games available.

Materials
The Mouse in the Maze
graph paper

Gathering data

As students investigate, look at their data. Some students might change more than one variable, such as the kind of animal and length of maze, in one experiment. Explain that if two variables are changed, the student cannot tell which variable, if any, explains the data.

Choose the partners you will work with as a team. Look at the set of cards in *The Mouse in the Maze.* The colored, punched cards stand for experimental conditions. You pick different cards to choose different conditions. You can choose the number of T's in the maze, the kind of animal to run the maze, and the number of the trial in the experiment. These are the variables you can change.

There is also a set of data cards on which numbers are printed. One side is marked "Time." It will give the time, in seconds, for one trip through the maze. The other side is marked "Mistakes." It will give the number of mistakes, or wrong turns, made in one trip. You can measure the animal's performance in either "Time" or "Mistakes."

If learning has taken place, it should be reflected either in reduced time or in fewer mistakes.

You can change some of the experimental conditions, but not others. For instance, assume that the temperature is 25°C and the maze is lit as brightly as a classroom. Each animal receives a small amount of food at the end of the maze. None of the animals has been in a maze before, and trials are made one hour apart.

Sample hypothesis: A mouse will make fewer mistakes on later trials than it makes on early trials. *If-variable*, number of trial; *then-variable*, number of mistakes. Variables to keep constant: type of animal (mouse) and number of T's in maze.

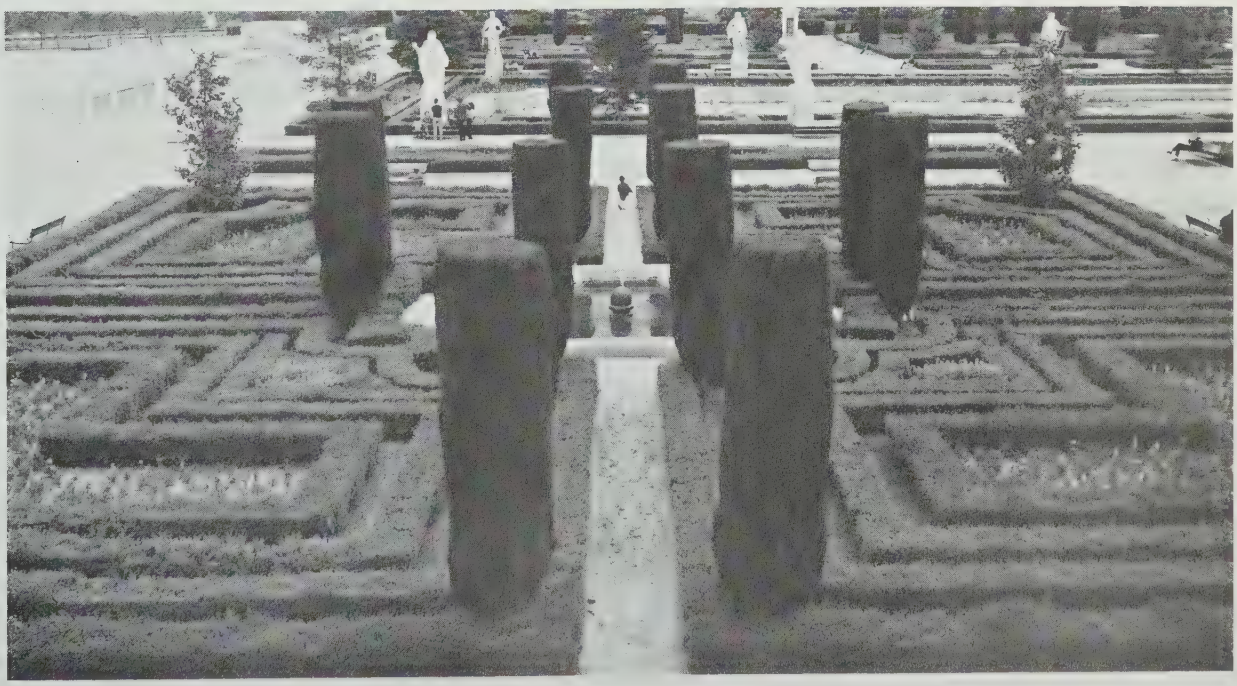
How to use the cards

First decide on the hypothesis you want to test. What is your *if-variable?* your *then-variable?* Which of the conditions that you can control will you need to keep constant? Follow these directions.

1. Select one green card. It shows which animal is being studied.
2. Select one orange card. It shows the number of T's in the maze.
3. Select one blue card. It shows the number of the trial for the animal in the maze.
4. Fit the three colored cards together. One hole should go through all three cards.
5. Roll the die. The number on the die tells the number of the data card you should use. The number will be from 1 to 6.
6. Select one side of the data cards to use, either "Time" or "Mistakes."



This housing development and garden both appear as mazes when seen from above. People soon learn to find their way through these mazes.



7. Place the three colored cards over the data card you have picked. Line up all the cards.
8. Read the number that shows through the hole in the colored cards. This number is either the number of seconds the animal took to run the maze or the number of mistakes it made.

Encourage students to ask further questions about the maze-learning behavior of rodents, especially questions that could be investigated using the simulation cards.

Repeat Steps 1–8. Do as many trials as you think you need to collect data for a learning-graph. Roll the die to select a new data card for each trial. If you have time, you may want to test another hypothesis.

For every simulated experiment that you do, record the conditions and results. Here is one example of a useful record of data. Your data-record does not have to be exactly the same, but it should keep your data organized.

Hypothesis: If the number of trials increases; then the time will decrease.

Animal	*T's in maze*	*Trial*	*Time (seconds)*
mouse	*8*	*1*	*85*
mouse	*8*	*3*	*66*
mouse	*8*	*5*	*56*
mouse	*8*	*7*	*59*

Analyzing data

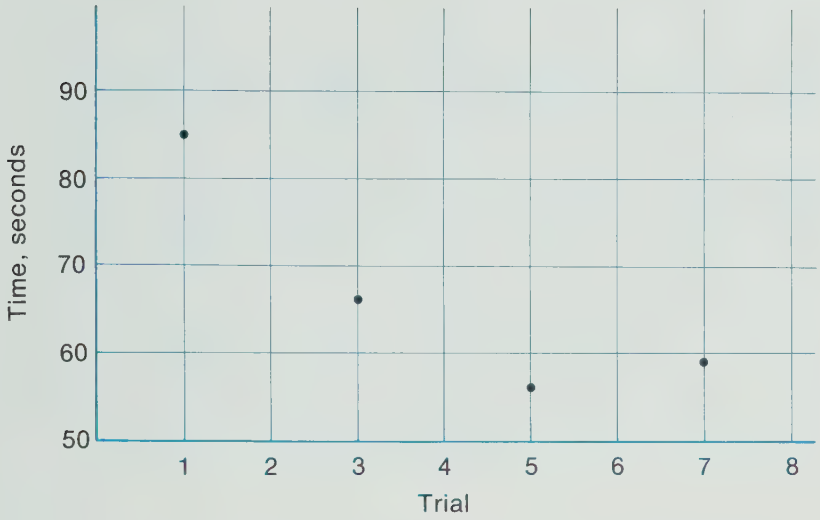
Make a learning-graph using the data from your experiment. Remember, your *if-variable* goes on the horizontal axis. Your *then-variable* goes on the vertical axis. Make a graph for each hypothesis you tested.

1. Did the animals learn? How can you tell?
2. Did all the animals learn at the same rate?
3. What similarities and differences can be found in maze-learning by humans and rodents?

The terms "interpolate" and "extrapolate" are not used in this program although the concepts are used in later investigations. Introduce these terms at your own discretion. Students should realize that predicting within the range of recorded values (interpolation) is usually more accurate than predicting outside the range of actual data (extrapolation).

Your learning-graph can also be used to make predictions. Look at this graph. Notice that there are points for Trials 1, 3, 5, and 7. Try to predict the time for Trial 2 or Trial 6. These predictions fall within the range of the data. It is also possible

to predict values outside the range of your data. Try to predict the time for Trials 10, 12, or 25. Which kind of prediction would you feel more sure about?



Make one or more predictions from the learning-graph that you made for this Investigation. Try to make both kinds of predictions. Then test your predictions by finding the actual data from the simulation cards.

Investigation 8-3
Can animals learn to escape?

This is an optional but valuable Investigation. If more animals are available, students can work in groups.

As a young child you may have learned to get out of your crib or playpen. In this Investigation, your class will do an experiment to find out if small animals can learn to escape from a flowerpot. What hypotheses can you think of to test in this Investigation? What variables will you have to control?

Sample hypothesis: A bright light near the flowerpot will slow down the rate at which a mouse learns to escape. They would need to control the amount of food, the type of food, and outside distractions.

Materials
mouse, hamster, or gerbil
flowerpot
food

Gathering data

In this Investigation, the whole class may work together. Place the flowerpot in the middle of a large table. Put small bits of

food around the pot. Put the animal into the flowerpot. Measure the time it takes to escape. Let the animal eat only one bit of food after each escape. Put the animal back into the pot and again measure the time for it to escape. Handle the animal gently.

Decide on a clear sign that the animal has escaped, such as "all four feet on the table." If the flowerpot is too high, some animals are reluctant to jump down, so another criterion might be necessary. If the animal is alarmed by noisy students, it may prefer to remain in the flowerpot.

During these experiments, try not to disturb the animal by getting too close or making loud noises. Repeat the experiment at least six times. Keep a record of the time required for the animal to escape each time. Make notes of any interesting behavior by the animal during the experiment. For example, does the animal try to escape as soon as you put it back into the flowerpot? Does the animal ignore the food when it escapes from the flowerpot?

Would you get the same results if there were no food outside the flowerpot? What would happen if you compared escape-times for a hungry and a well-fed animal? Make a learning-graph from the data collected by the class.

The food outside the flowerpot acts as bait for the animal and a reward for escaping. A well-fed animal should be less interested in escaping in order to get the food and might well take longer. But the escape behavior is probably in part innate curiosity or dislike of a confined space.

Analyzing data

1. Did the animal show signs of learning?
2. Did the animal eat one bit of food each time it escaped?
3. What variables did you have to control?
4. How does this learning-graph compare with the ones you made in Investigation 8-2?
5. What other animals could be tested for learning in an escape situation? What equipment would you need?

Encourage students to discuss any unsuccessful learning situations they may have encountered in school. The discussion can lead students to realize that factors other than one's innate intelligence often determine how much one learns.

Extend Your View 8-1
Can ants learn?

Can you identify changes in behavior that could be used to measure learning? Describe a task, other than going through a maze, that might be used to study whether or not ants can learn.

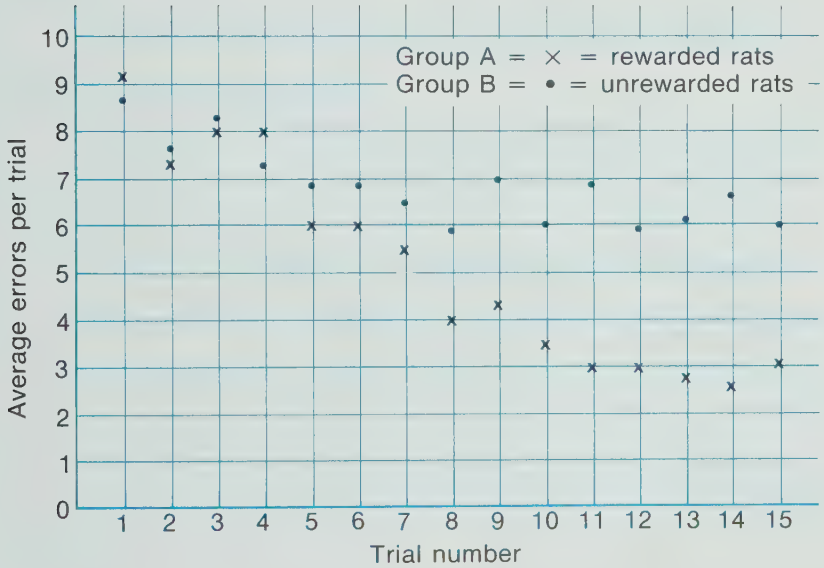
Extend Your View 8-2
Studying with the radio on

Can you design an experiment to measure changes in behavior? Some people think that listening to a radio prevents learning. Do you think so? Design an experiment to test a hypothesis about listening to the radio and learning.

Extend Your View 8-3
Learning and rewards

Have you learned to interpret a learning-graph? Two groups of rats were tested in a maze once each day. The maze had 14 T's. There were eight rats in each test group. Rats in Group A were rewarded with a small amount of food when they got through the maze. Rats in Group B were not rewarded.

Here are the results of a series of trials on Group A and Group B. Notice that the time plotted for each trial is the average for the group of eight, not an individual score. Answer these questions and give reasons for your answers.



1. Did both groups learn something?
2. Which group learned more?
3. Which group learned faster?
4. What results would you expect from Group A if the same experiment were continued for 50 trials?
5. What hypothesis can you make to explain why both groups seemed to do equally well at first?



Unit TWO

The environment affects living things



9

What is a suitable environment?

After you complete these Investigations, you will be able to

1. hypothesize what kind of environment would best match an organism's needs.
2. infer how an organism's response to its environment can help it to survive.

What do you usually do when you become too warm? Your body does some things automatically. For example, you may perspire. You may also choose to remove some clothing, move to a shady spot, drink something cool, or go swimming. These are ways you respond to your environment when you are too warm. How do you respond to your environment when you become too cold? Organisms must respond to their environment in order to survive. In these Investigations, you will study the responses of some organisms.

Investigation 9-1
Making a home for an animal

In this Investigation, you will try to provide a suitable environment for a small animal. You can buy your animal at a pet store. Or you may want to find and capture an animal yourself. You may want to have several animals of the same kind. The animal

Students should bring in their organisms as they collect them. Have them begin by observing their organisms. Ask questions such as: "Which part of the container does your animal prefer?" "Does it move about or mostly stay in one place?"

could be as small as a beetle or sow bug, or slightly larger, like a grasshopper or earthworm.

Some animals, such as turtles, carry bacteria that cause diseases in people. Some animals, such as spiders or ants, may bite. Handle the animals carefully, so they do not harm you and you do not harm them. Avoid animals like spiders that are difficult to pick up without injuring. Remember always to wash your hands after handling any animal.

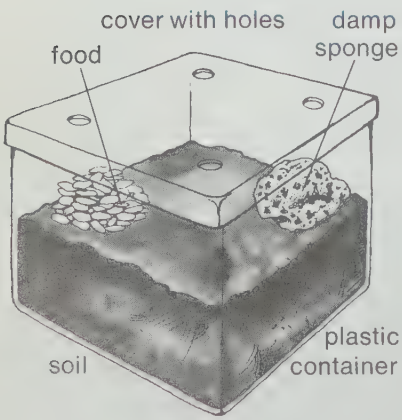
You might have a favorite small organism that you would like to work with. The photographs on pages 109 and 110 may give you some ideas. You will need a collecting jar. If the jar has a lid, you will need to punch holes in it so that the organism can breathe. You can also make a similar cover from aluminum foil and a rubber band.

These hints may help you in your search. Beetles can be found in grassy areas. Look on the ground under boards or leaves or on the leaves of growing plants. Sow bugs and earthworms are usually found in dark, damp places. Look under rocks, old leaves, or rotting logs. Sow bugs can be captured by placing a raw, hollowed-out potato in a grassy area. Earthworms are easily found under old leaves or on the surface of the soil right after a rain. Toads can sometimes be found in a grassy area.

Some snails can be found in ponds. Other snails live on land and can be found on plants in grassy areas or on tree trunks. You might also look for a cricket or grasshopper in the same area.

If you have purchased organisms for the class, try to get some information on their environmental preferences from the pet store or the supply house.

Mealworms are the larvae of grain beetles. You are not likely to find any "wild" ones. They are usually sold in pet stores as food. Snails can also be bought in pet stores.



Materials

collecting jar with cover
collecting net (optional)
milk cartons or plastic containers to build a home
other items such as soil, water, and food
reference books

Gathering data

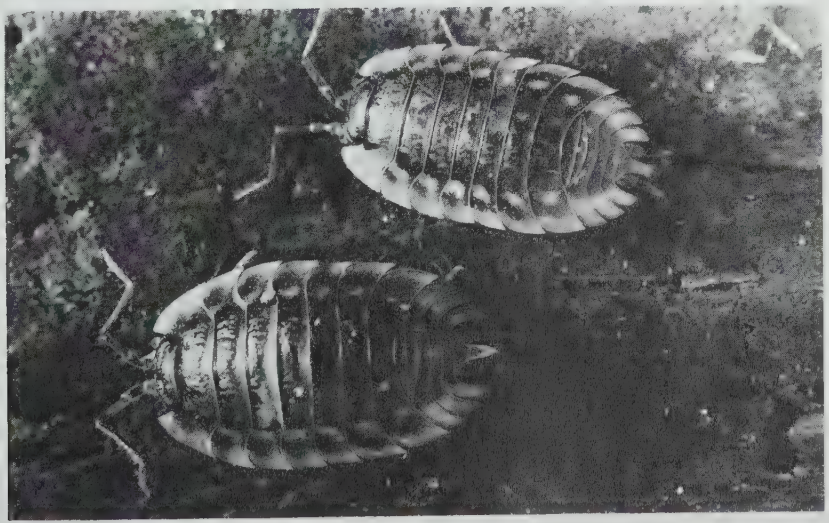
What kind of information will you need to design a home for your animal? What does your animal eat? Consider the environment where you found your animal. Was it moist or dry?



earthworm



cockroach



sowbugs



leaf beetle



snail

toad



Was it light or dark? Was it hot or cold? Does your animal need anything besides food, water, and air? You will probably want to read about your organism to learn more about its natural environment. Your teacher may have books on the subject or you can use the library.

How does your animal respond to the conditions in the home you have made? Part of its response may be due to fear of you or its new surroundings. The home you have made is based on a hypothesis. You hypothesized what conditions would suit your animal. If necessary, you may have to change the hypothesis and the conditions.

The organism's natural environment is probably the most important clue to use when designing a home. Some of the needed information can come from books or periodicals. Students should test any information from these sources.

Let students design the homes for their organisms without too much interference. Try to watch for extreme conditions that might harm the organism. With proper care and handling, the same organisms can be used in the next Investigation.

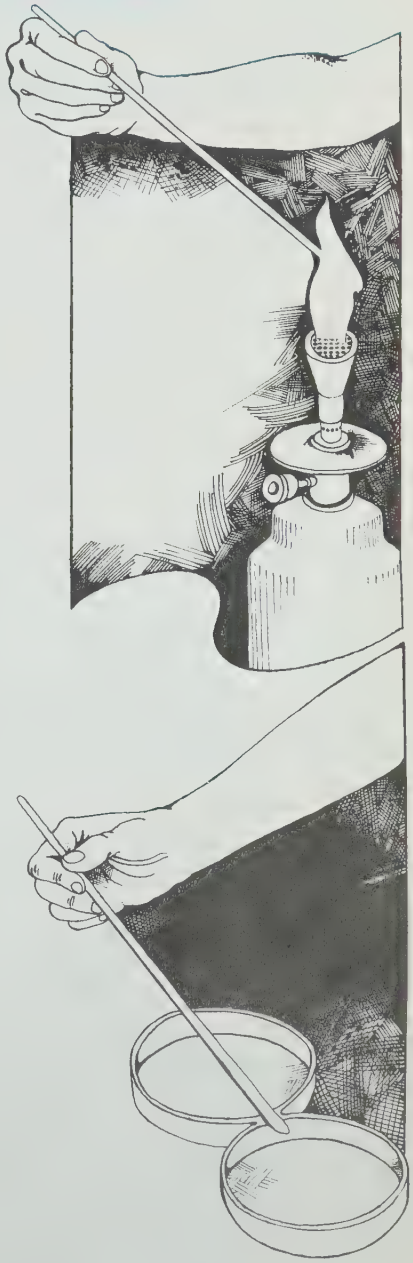
Analyzing data

Make a list of the variables in an environment that might affect an animal. Describe the home you built and why you included each item. How did you take care of each variable? How much of the design was a result of your observations? How much was a result of what you read? Did the data that you collected support your original hypothesis?

Investigation 9-2
How does your animal respond to different conditions?

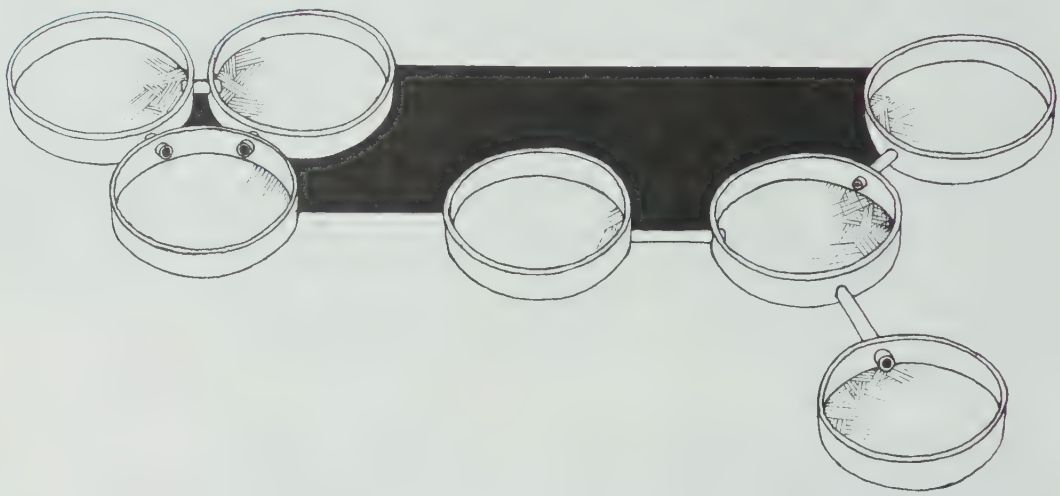
In Investigation 9-1, you made a list of important environmental variables. In this Investigation, you will design an experiment to find out how your animal responds to one of the variables. Choose a variable to test. Make a hypothesis about how your animal will respond to this variable. You might want to use one of these pieces of equipment in your experiment. You might want to change or improve the equipment. Or you may design an entirely different method. Remember that you should control the variables that you are not studying.

Norma wanted to test her animal's response to different amounts of light. She joined two plastic Petri dishes as shown in this drawing. She covered one dish with black paper and left the other dish clear. Her animal was able to move easily between the dishes and select the one it "preferred." Norma placed a light over the clear dish. She used light bulbs of different wattages.



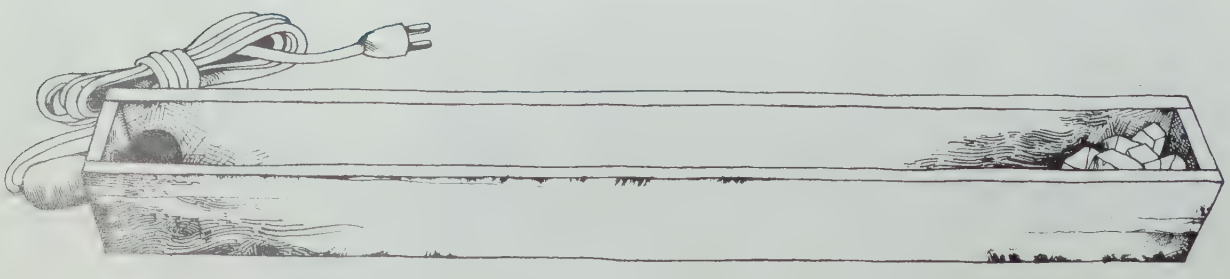
Joe wanted to test his animal's response to heat. He made chambers by joining three Petri dishes to make a triangle. Joe placed ten of his animals in one chamber. He then put a beaker containing water at 30°C on top of one chamber. He put a second beaker of water at 15°C on the second chamber and a beaker of ice water at 5°C on the third. After 15 minutes, he counted the number of organisms in each chamber.

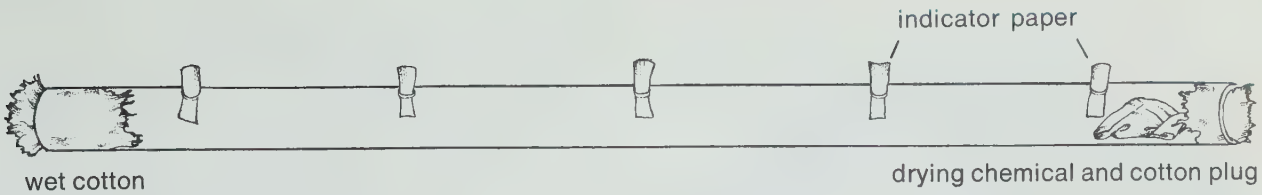
Plastic Petri dishes can also be joined by glass or plastic tubing. Make holes for the tubes with a hot glass or metal rod. When dishes are joined by tubes, the distances between dishes can be varied.



These examples are suggestions for students to consider. The actual hypothesis being tested is not stated. Students can be asked to infer the *if-variable, then-variable,* and hypothesis. Note that Joe used ten organisms of the same kind. The larger the population used, the more confidence one has in generalizing the results.

Manuel also wanted to test a hypothesis about temperature, but he used different equipment. He made a long wooden box. He placed a small light bulb that was painted black at one end. He placed ice at the other end. Manuel reasoned that the temperature would vary evenly from one end of the box to the other. His animal would be able to find the temperature that suited it best. He covered his box with a sheet of thick, clear plastic. He taped the plastic to the box. Then he punched holes through the plastic. He left some of the holes open so that the animal could breathe. Through the other holes, he inserted thermometers to measure the temperature inside the box.



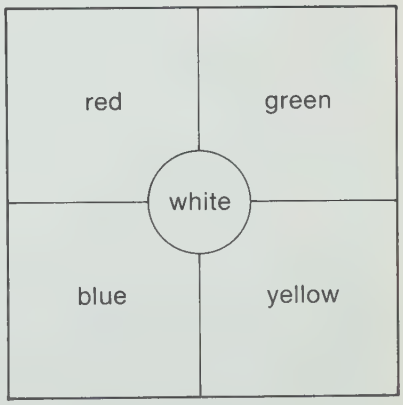


Ruth wanted to make a chamber that could be used for testing responses to light, temperature, and humidity. She used a long piece of plastic tubing. She drilled holes along the length of the tubing for thermometers or other items. Ruth warmed one end of the tubing with an electric heating pad. She made the other end cold by using a bag of ice. She inserted thermometers through the holes to test her hypothesis about temperature.

The next day Ruth used the same tube to test a hypothesis about humidity. She placed wet cotton at one end and drying chemicals at the other. This made the humidity gradually vary from one end to the other. To measure the humidity, she stuck some special test paper through the holes.

To test her hypothesis about light, Ruth covered the tube with pieces of black paper. Each piece of paper was about five centimetres wide and was wrapped all the way around the tubing. The paper covering one end had no holes in it. Ruth used a paper punch to make 10 holes in the piece that went on next. She made 20 holes in the third piece, 40 holes in the fourth, and 80 holes in the fifth. Each piece of paper contained twice as many holes as the one before. As the number of holes doubled, so did the amount of light entering a section of the tubing.

Eric decided to test a hypothesis about color. He made a color board like the one shown. He made sure that it was level before placing his animal in the center. Eric placed his animal on the board with its head pointing in a different direction on each trial. Why did he do this?

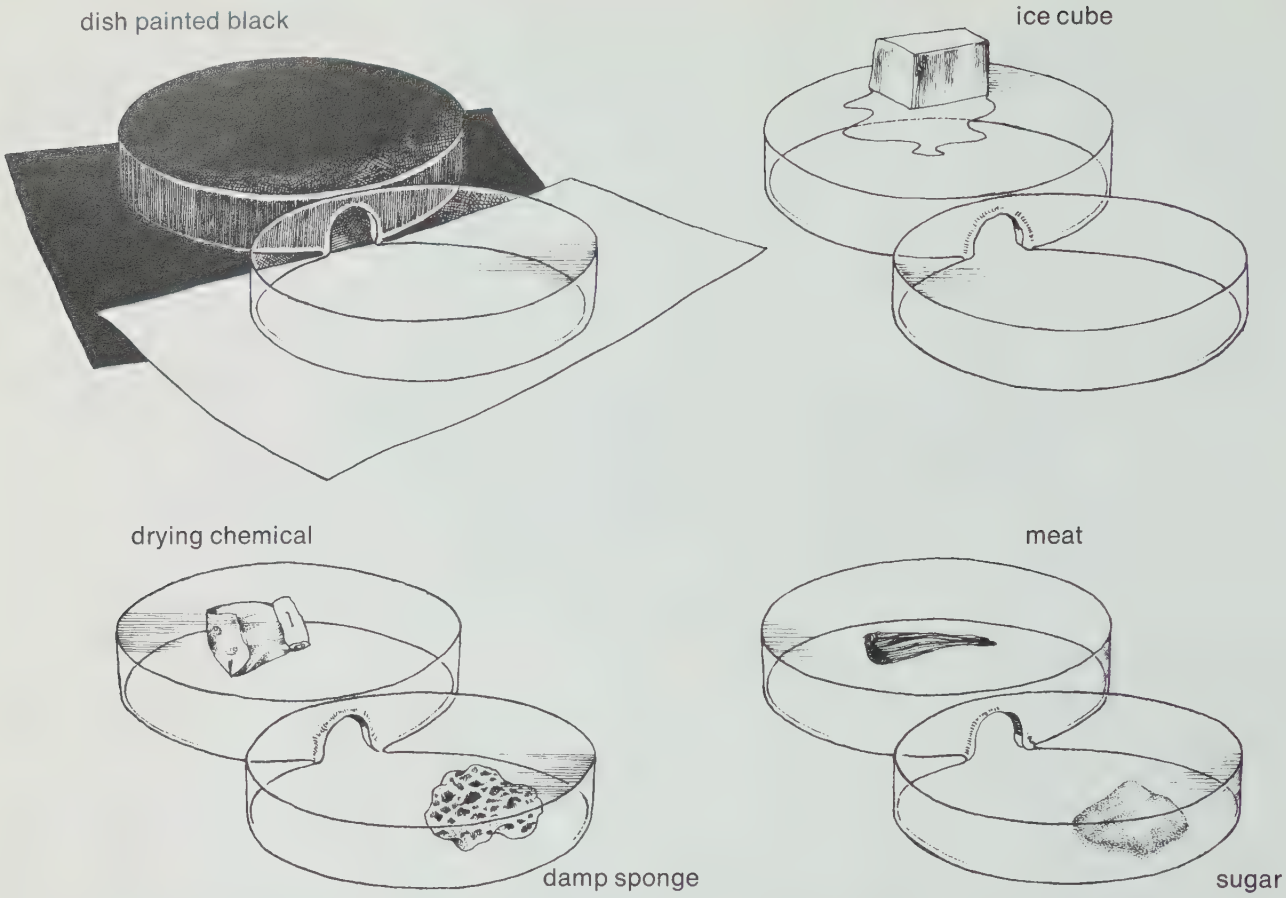


Materials
small animals
equipment to test your hypothesis

Have students return surviving organisms to the environments in which they found them or similar environments.

Gathering data

Before you actually begin your experiment, write down the variable you selected, your hypothesis, your plan of action, and the materials you will use. It might be helpful to use the *Checklist* on page 86. Discuss your plan with your teacher before you begin. You may want to work in small groups.



What hypothesis should each setup test?

Analyzing data

You can record a summary of each group's findings on the chalkboard, on a transparency, or on mimeographed sheets. During a class discussion, a composite picture of animal responses can be developed.

Does your data support your hypothesis? If your hypothesis was not supported by your data, what did you learn from your experiment?

Present your results to the class. Compare the response of different organisms to the same environmental variables. Try to infer how the behavior of each animal would help it survive. In what ways do people change their behavior in response to changes in their environment?

Extend Your View 9-1
Making a home for people

Can you hypothesize what kind of environment would best match an organism's needs? You have already thought about the conditions that make an ideal environment for some small

animal. List the environmental conditions that people need. Which needs do they share with small animals? Do most people live in the kind of environment that meets these needs?

Extend Your View 9-2
How does a rattlesnake survive?

Can you infer how an organism's response to its environment can help it to survive? A sidewinder rattlesnake lives in desert regions. During the day, it makes a depression in the sand with its body. It then coils into the depression and throws sand over its body until it is almost completely covered. At night, the sidewinder becomes more active and does its hunting. Try to identify the possible survival value of this behavior.





10

How does light affect euglenas?

After you complete these Investigations, you will be able to

1. predict the response of euglenas to variations in the intensity and color of light.
2. infer how different responses to light help organisms to survive.

Euglena (yoo GLEE nuh) is the name of a group of organisms. If you have observed water from a pond or ditch through a microscope, you may already have seen some of them.

Be sure to have small containers of the *Euglena* culture ready.

Your teacher has been growing some euglenas for you to study. The solution is green because it contains **chlorophyll** (KLOHR uh fil). Chlorophyll is the substance that gives all green plants their color. Chlorophyll can absorb energy from sunlight. Green plants use this energy to turn water and carbon dioxide into carbohydrates, such as sugars and starches.

Cellulose is also a carbohydrate, but humans cannot digest it.

These carbohydrates are a source of energy for the plants and other organisms. Almost all other organisms eat plants or eat animals that eat green plants. You probably eat both. The manufacture of carbohydrates by plants is called **photosynthesis.** Oxygen is produced during the process. In fact, most of the oxygen that organisms use comes from green plants.

An organism must adjust to the changes in its environment to survive. In this Investigation, you will study how euglenas respond to changes in light.

The emphasis right now should be on the observation of euglenas, not conclusions about photosynthesis.

Investigation 10-1
How do euglenas respond to light and dark?

Look again at the solution the euglenas are in. Where is the chlorophyll in the solution? Is it in the euglenas? You will need a microscope to look at the solution and find out. There are directions for using a microscope and preparing a slide in Appendix D. Euglenas move very fast. Your teacher will show you how to slow them down.

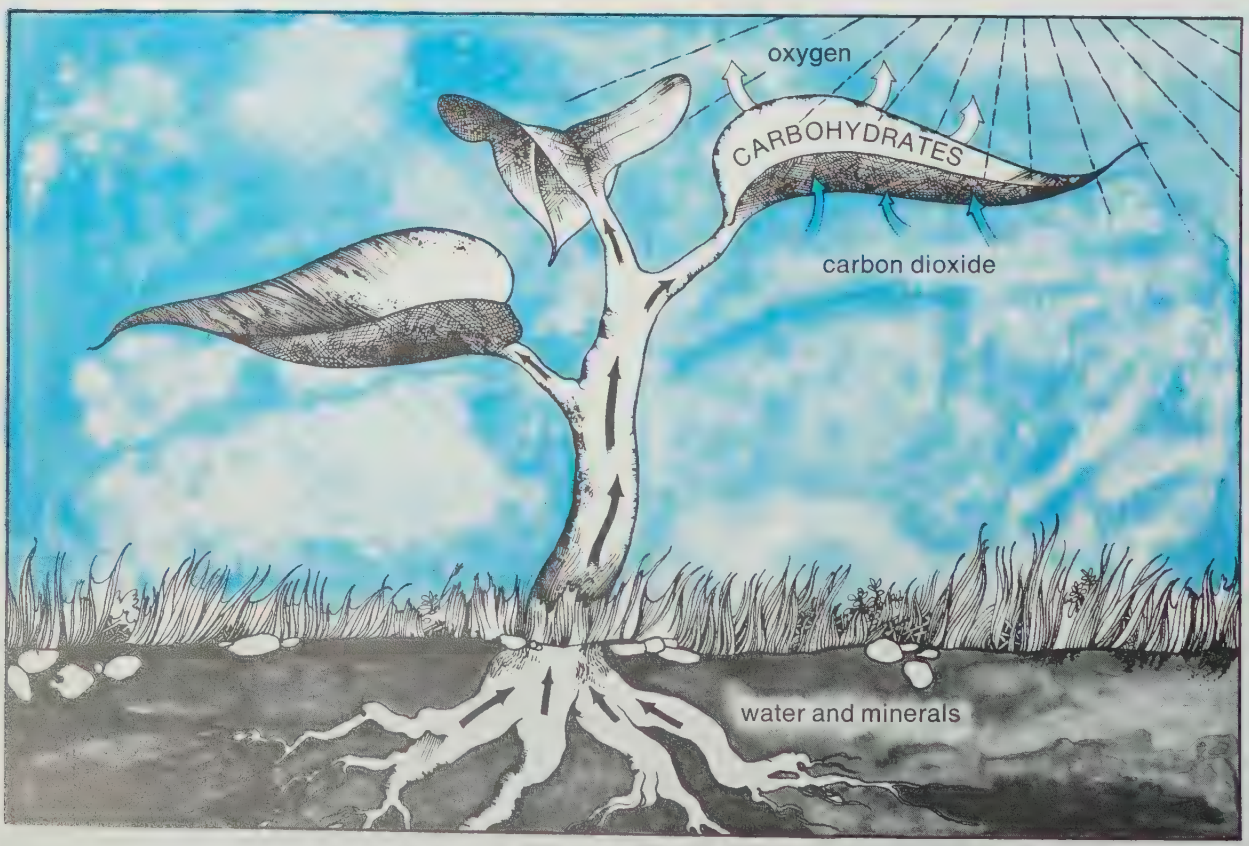
Have students use the cotton or methyl cellulose sparingly to slow down the euglenas.

Examine your slide under the lowest magnification of your microscope. You should see many euglenas swimming about. To observe a euglena more closely, use the highest magnification of your microscope.

The flagella of euglenas normally cannot be seen. To make them more visible, add a drop of methylene blue to a drop of *Euglena* culture. Then cover the slide with a cover slip. The methylene blue kills the euglenas, so prepare only one slide as a demonstration.

Can you see a reddish-orange spot toward one end of a euglena? If not, try using the diaphragm of the microscope to reduce the amount of light slightly. A long whip or flagellum

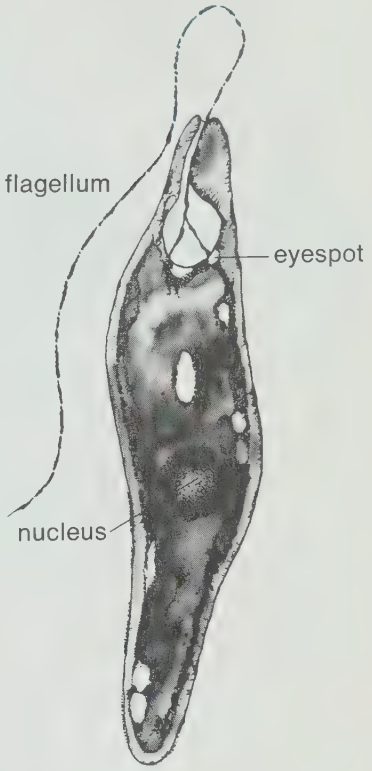
The chlorophyll in the leaves absorbs energy from the sun to make high-energy carbohydrates.



(fluh JEHL uhm) is attached to the euglena next to the reddish-orange spot. This spot contains substances that seem to be sensitive to light. Try to discover how a euglena moves. Which end usually goes first as it moves?

How would you accurately describe a euglena to someone who has never seen one? That is a good test of how careful your observations are. You might want to make a drawing.

Many organisms that contain chlorophyll cannot move about. What advantage could it be for euglenas to be able to move? How could it help them survive? How do you think euglenas would react if they were placed in an environment with light and dark areas? Make a hypothesis and record it in your notebook.



Materials

container of euglenas
black construction paper
masking tape
paper punch
scissors

Gathering data

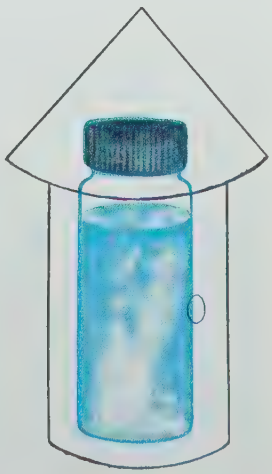
Here is one simple method to test how euglenas respond to light and dark. The container of euglenas should be filled three-quarters full. Why should you not tighten the lid or stopper completely?

Allow students who think of other ways to test their hypotheses to try their methods.

Cut a piece of black paper large enough to wrap around the container. Make a hole in the center with a paper punch. Then tape the paper so it fits snugly around the container. Cut and tape another piece of paper to form the cap. Light should come in through only the hole you made.

If students make the holes in the paper masks near the top or bottom, these masks can be used again in Investigation 10-2.





Now slip off the paper cover and place it next to the container. Draw a picture of the container to show where the euglenas are before the experiment begins. You cannot see individual euglenas without a microscope. But large numbers of them are easily seen as a patch of green. Slip the paper cover back on. Then put the container where it will get light for at least two or three hours before the next class meeting. Why do you think the container should not be in direct sunlight?

On overcast days or for classes that meet early in the morning, provide the euglenas with several hours of artificial light before making observations.

At the next class meeting, carefully remove the paper cover without stirring up the liquid. Stand the cover beside the container. Sketch the container to show where the euglenas are. Compare the positions of the euglenas with the position of the hole in the cover.

Analyzing data

1. Does your data support your hypothesis? Did the euglenas respond in the same way for your classmates?
2. Inferring from your data, write a short paragraph on how the euglenas' response to light might help them survive.

Investigation 10-2
What kind of light do euglenas prefer?

Before letting them proceed with their investigations, be sure the students understand that:
1. White light is really composed of different colors.
2. A red object, for example, appears red because it absorbs the other colors and reflects the red color to the eye.
3. A blue filter absorbs all colors except blue, which it allows to pass through.

You have seen that euglenas prefer light to darkness. And you have inferred how this behavior might help them to survive. But what kind of light do they prefer: direct sunlight, bright indirect light, or shade?

White light is composed of many colors. You can see this by placing a glass prism in the path of a strong beam of light. Would different colors of light affect the behavior of euglenas? Make a hypothesis about how euglenas would respond to different intensities of light or different colors of light. Then design an experiment to test your hypothesis. You may get some ideas from the setup in Investigation 10-1.

Materials

See what materials your teacher has available. You can use these or other materials that you collect yourself.

Gathering data

Some students may want to investigate the effect of temperature or nutrients on the reactions of euglenas to light.

Write down your plan of action. An accurate description of an experiment helps you to interpret the data. Use the *Checklist* on

page 86 to check your plan. You may find it helpful to make drawings to illustrate your experiment.

Analyzing data

1. What did your experiment show? Does the data support your hypothesis? Did another group perform a similar investigation and get similar results?
2. Compare data with your classmates who did different experiments. Describe the possible survival value of the euglenas' response to light.

If the students' conclusions are contradictory, redirect everyone's attention to the data-gathering procedures. Raise new questions, for example, about the quality of the filters used. Some blue filters may allow a considerable amount of green light to pass through.



These plants, like the microscopic euglenas, need light. The greenhouse allows light to enter while controlling other variables.

Extend Your View 10-1
Where do euglenas live in this pond?

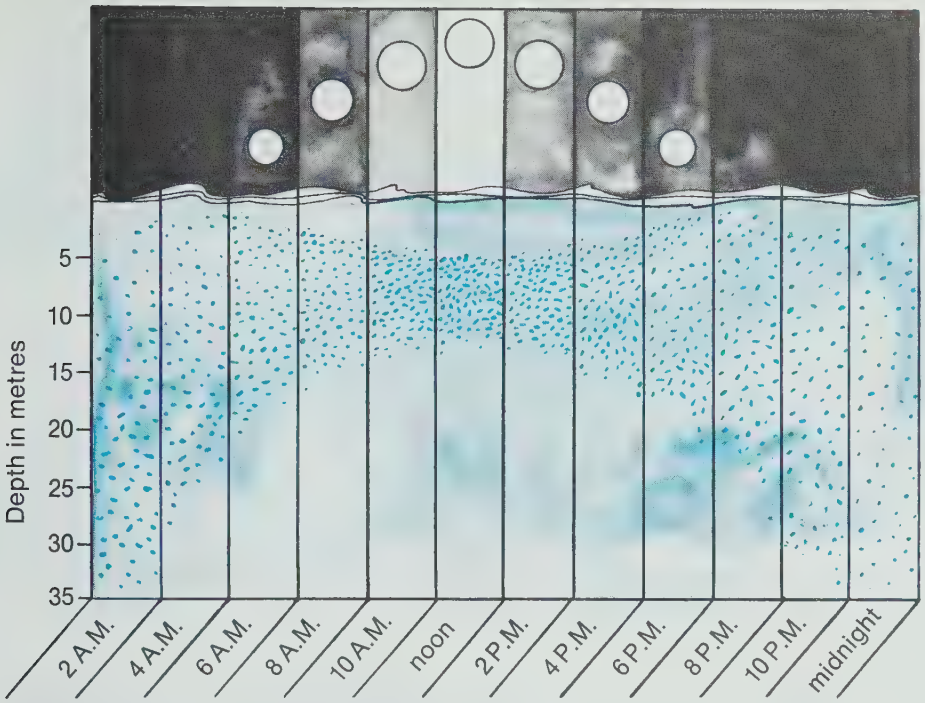
Tell students that red light does not penetrate water nearly as well as blue light does. The water's surface usually looks intensely blue when viewed from deep underwater.

Can you predict the response of euglenas to variations in the intensity and color of light? Many euglenas live in this pond. Would you expect them to be spread evenly throughout the pond? Where would most of them be on a bright, sunny day?

List the lettered parts of the pond, in order, from most euglenas to least. Then write a short statement explaining your predictions. How could you test your predictions?

A. under some red food coloring that was released into the pond from a nearby bakery
B. at the surface of an open area
C. under a boat
D. near the surface of an open area that is partly shaded by trees





Extend Your View 10-2

The sun and ocean-dwelling organisms

Can you infer how different responses to light help organisms to survive? Organisms similar to euglenas live in the ocean. Scientists have found that these organisms travel daily between the ocean's surface and deeper waters. This diagram shows the vertical movement of one group of organisms during a 24-hour period. Study the diagram carefully. How might vertical movements help these organisms to survive?



11

What influences seed germination

After you complete these Investigations, you will be able to

1. use experimental data to identify what conditions affect the germination of different seeds.

Seeds pass life on from generation to generation in many kinds of plants. Seeds are a way for life to almost stop . . . and then revive. They may **germinate** (JUR muh nayt), or sprout, years after the parent plant died.

The length of time that seeds can stay inactive, or **dormant,** varies. Seeds from quaking aspen trees generally die after eight weeks in storage. But red clover seeds have germinated 100 years after they were formed. Some seeds have remained dormant even longer.

A Japanese scientist, Dr. Ichiro Ohga, studied some lotus seeds from an ancient lake bed. The lake had filled with peat and had dried up. Peat is dead vegetation that has slowly rotted and packed solid. The seeds were large, with thick, hard coats. Some of the seeds were able to germinate, even though they were 1000 years old.

A mining engineer found Arctic lupine seeds under about three to six metres of frozen soil in northwestern Canada. These seeds were given to a group of Canadian scientists. They placed some of the seeds on wet paper in a dish. Some of the seeds germinated within two days. The seeds were estimated to be about 10 000 years old. The plants in the photograph on the next page grew from the Arctic lupine seeds.



Discuss some everyday experiences. Ask why seeds on the kitchen shelf, such as rice and beans, do not germinate, or why grass seeds for lawns do not germinate in the bag.

How can seeds germinate after such a long time? Since they were found outdoors, why didn't the seeds germinate long ago? Can you make seeds germinate earlier or later than they would in nature? In these Investigations, you will work with dormant and germinating seeds. You will make seeds germinate, and test their responses to the environment.

Investigation 11-1
How do seeds respond to water?

If seeds are planted on Monday, students have four consecutive days to make the early observations that are important for determining the minimum time for germination and the order in which seeds germinate. The kinds of seeds recommended for these Investigations should begin to germinate by the fourth day after "planting."

The outside part of a ripe seed, the seed coat, is usually hard and dry. Water must soak through the seed coat before the seed can germinate. You will investigate the ways water affects seeds. You will also find out how the seed coat can be treated to affect germination.

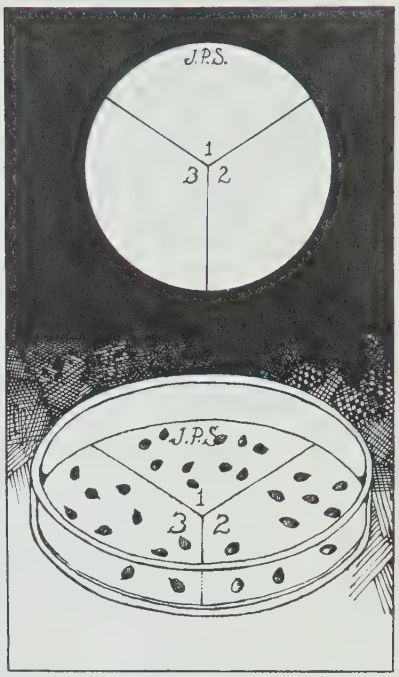
Materials

2 Petri dishes
8 pieces of filter paper or 4 paper towels
ball-point pen
triangular file
40 untreated seeds of one kind: black locust, honey locust, or silk tree
20 acid-treated seeds (the same kind as the untreated seeds)
2 small plastic bags
ruler
scissors

Do not use felt-tip markers, since their ink is more likely to run when wet.

Gathering data

1. Take 4 pieces of filter paper, or cut out 4 disks from paper towels. The disks should fit inside the smaller half of the Petri dish. Label one disk as shown.
2. Place the 4 disks in the Petri dish with the labeled disk on top. Add enough water to soak the paper and leave a thin film on the top.
3. Take 10 untreated seeds from one container. Space them over Section 1 in the dish.
4. Take 10 more untreated seeds and file a small groove in each one. File just through the seed coat on one flat side of each seed. Put them in Section 2 with the grooved side down.
5. Space 10 acid-treated seeds evenly over Section 3. Your teacher soaked these seeds in concentrated sulfuric acid for 20 minutes. Then the acid was washed off with water and the seeds were dried.
6. Cover the dish and place it in a small plastic bag. This slows down evaporation of the water in the dish.
7. Put your dish on a flat surface.
8. Do not open the dish except to add water. Add more water if it looks like the paper is drying out.
9. Write down the kind of seed you are using. Make a table to record the number of seeds that germinate in each section each day. Keep a record for seven days.



During the week after "planting," all the seeds should be kept in a place where the temperature range is from 15° to 25°C. Do not send the seeds home for weekend observations. Conditions will vary from home to home, and the seeds will be disturbed. Try to make weekend observations and record the data.

How does water affect seeds before they actually sprout? Here is a way to tell without disturbing your first set of seeds.

1. Prepare another Petri dish with filter paper or paper towels. Label the top piece of paper as before, and add water.
2. Choose 10 seeds from each group: untreated, treated, and grooved. Measure the seeds by lining up the 10 seeds in each group end to end. Measure the total length of each group in millimetres (mm).
3. Space each group of seeds in the dish, exactly as you did before. Put the cover on the dish and place it in a plastic bag.
4. Tomorrow and the next day, remove one group of seeds at a time. Line each group up on a damp paper towel and measure the length of the group. Then replace the seeds, cover the dish, and put it back.
5. Make a data-table to record the lengths you measure. Also record any other changes that you observe.

Some students might also be interested in finding the mass of each group of 10 seeds as another way to quantify water uptake. A balance with 0.1-g graduations will be necessary. The measurements should be discontinued before signs of germination appear, usually within two or three days.

Maybe you can think of a better way to observe changes in seeds before they germinate. If you can, use your method.

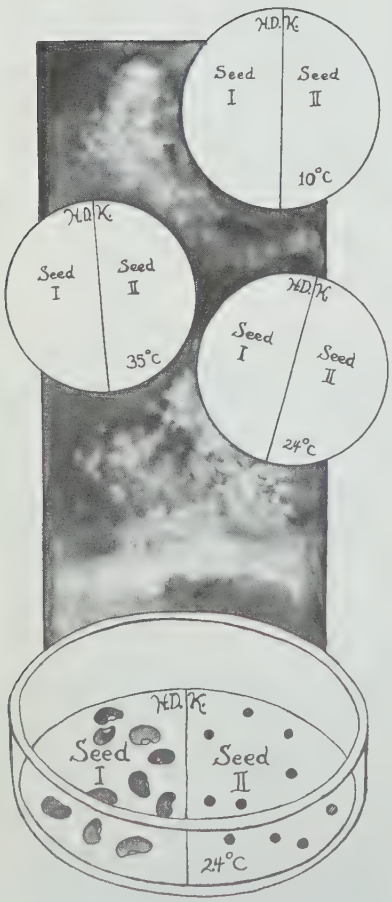
Some students may want to repeat the experiment using treated seeds kept in a dry dish as a control.

Analyzing data

Compare results with other students doing this Investigation. Write a short report for classmates who worked on other Investigations. Include the hypotheses you tested. Also include your data, your analysis of the data, and any new questions you thought of.

1. Did any of the seeds look different after two days in water? What can you infer was happening?
2. Did you observe any differences among the three groups of seeds?
3. What inferences can you make to explain the data from the untreated seeds?
4. How might a seed coat that resists letting water through be useful for seeds?

If you have thought of any other experiments to do, write down your plan of action. Check with your teacher before starting.



Investigation 11-2
How does temperature affect germination?

A goldfish responds to temperature changes by changing its breathing rate. Will seeds respond to temperature changes by changing their germination rates? Do different kinds of seeds have different responses?

Materials

3 Petri dishes
12 pieces of filter paper or 6 paper towels
ball-point pen
2 kinds of seeds, 30 of each kind
3 small plastic bags

Gathering data

1. Take 12 pieces of filter paper, or cut 12 disks from paper towels. The disks should fit into the smaller half of the Petri dish. Label 3 disks as shown.



You might want to discuss other forms of seed-dispersal, such as animals picking up burrs or eating fruit and excreting the seeds.

The wind can carry seeds away from the adult plant.

2. Place 4 disks in each of three Petri dishes with the labeled ones on top. Then add enough water to soak the paper and leave a thin film on top. Is it important for all three dishes to have the same amount of water?
3. Space 10 seeds of one kind over half of one dish. Add 10 seeds of another kind to the other half. Prepare your other two dishes in the same way.
4. After you have placed your seeds, cover the dishes. Place each dish in its own plastic bag. This will reduce evaporation of the water, especially at the warmer temperatures.
5. Keep the seeds in a place where the temperatures will be nearly constant. Put one dish in a refrigerator (at about 10°C). Keep the second dish at room temperature (about 20°C). Put the third dish in an incubator (at about 35°C).
6. Check the dishes daily for germination. Add more water if the surface begins to look dry. Otherwise, do not remove the cover.

If classroom temperature changes by more than a few degrees overnight, a second incubator may be necessary to keep the room-temperature dishes at a constant temperature. Incubators or constant temperature boxes should be kept in a part of the room where they will not be exposed to direct sunlight. The boxes do not have the capacity to cool below the outside temperature. The temperature in "constant" temperature boxes varies with the distance from the control unit.

If possible, adjust the thermostat of the refrigerator so the temperature is between 10–14°C. At temperatures lower than this, seed germination may not occur within the seven-day observation period.















Molds will probably grow on some of the seeds, especially at 20° or 35°C. Moldy seeds should be removed or they will rapidly contaminate the others. If any students want to know if moldy seeds germinate, the seeds can be transferred to other covered dishes and kept in the same environment.

7. Keep a record of your data for seven days. Some seedlings may cover up seeds that have not germinated yet. Remove the seedlings if you cannot see the ungerminated seeds.
8. In a table, record for each day the total number of germinated seeds in each half of each dish. For example, take corn seeds incubated at 22°C. Suppose no seeds germinated during the first three days. Then six germinated on the fourth day, and two more on the fifth. Your table would look like this.

Seed type: corn	*Temperature: 22°C*
Day	*Total seeds germinated*
1	*0*
2	*0*
3	*0*
4	*6*
5	*8*
6	–
7	–

9. Write down below the data-table any other observations you make. These observations may help you to interpret the data on germination.

Analyzing data

Compare results with other students who did this Investigation. Write a short report for classmates who did not do this Investigation. Include the hypotheses you tested. Also include your data, your analysis of the data, and any new questions that you thought of.

1. In what order did the seeds begin to germinate?
2. Did any kind of seed germinate at the same rate at all three temperatures?
3. How would it be useful for seeds to react to variable temperatures?
4. Look at the seeds that failed to germinate. Show these seeds to people who worked with Investigation 11-1 and ask what they think. Cut open some of these seeds. How do they compare with sprouted seeds? Was failure to germinate due to water not getting inside? Do you have data to support this inference?

Students who hypothesize that a fluctuating day-night temperature would be natural and ideal for seed germination should be encouraged to test their hypotheses. They could simply turn off the incubators overnight (if it does not interfere with other experiments).

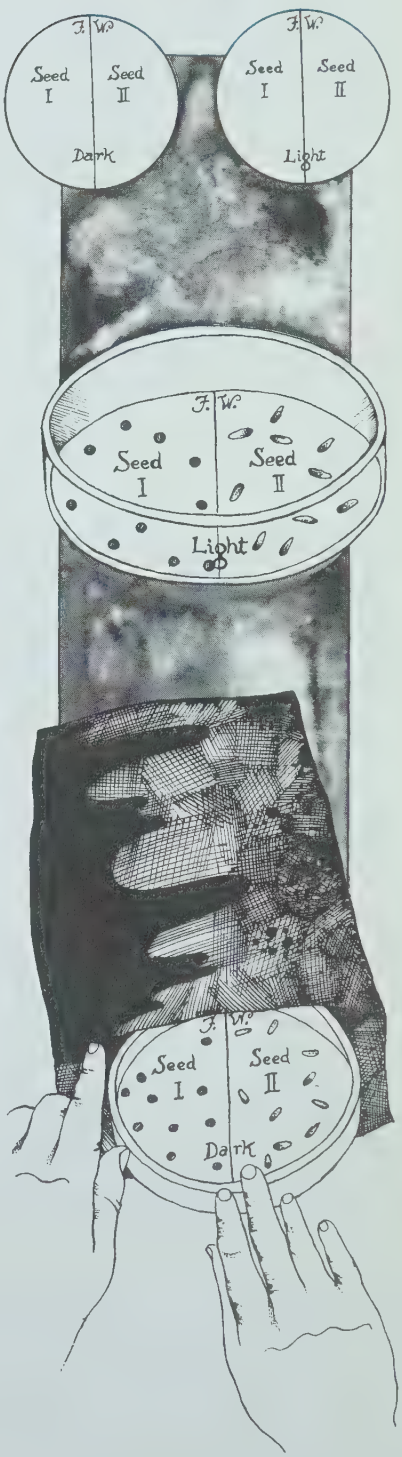
If you have thought of any other experiments to do, write down your plan. Check with your teacher before starting.

Investigation 11-3
Do seeds respond to light?

Seeds that usually need light to germinate will germinate in darkness if, after they are wet, they receive sufficient light to trigger growth.

Green plants cannot live very long without light. But what about their seeds? Most seeds lose their green color as they ripen. Do seeds need light to stay alive? Do they need light to germinate?

Materials
2 Petri dishes
8 pieces of filter paper or 4 paper towels
ball-point pen
2 kinds of seeds, 20 of each kind
black plastic sheeting
small plastic bag
tape
scissors
medicine dropper



Gathering data

1. Take 8 pieces of filter paper, or cut 8 disks from paper towels. The disks should fit into the smaller half of the Petri dish. Label 2 of the disks as shown.
2. Place 4 disks in each dish with a labeled disk on top.
3. On one half of the dry paper, space 10 seeds of one kind as shown. Add 10 seeds of a different kind to the other half. Prepare your second dish exactly the same way.
4. Now, quickly but carefully add water along the edge of the dish marked "Dark." The disks should be soaked. But stop adding water if the seeds start to move around.
5. As soon as the water is added, seal the dish in the black plastic sheeting. No light must enter. Set the dish in the place your teacher indicates.
6. Add water to the dish marked "Light." Why should you add the same amount of water to each dish? As soon as you add water, seal the dish in a clear plastic bag. These seeds should receive continuous light. Artificial light can be provided overnight. Do you think the temperatures of both dishes should be the same?
7. Do not open your dishes for seven days. You can observe the lighted seeds each day without opening the dish. What can you observe?

If the dishes fog up, remove the moisture by lightly tapping the cover.

8. At the end of seven days, open both dishes for observation. Record how many seeds of each kind germinated in the dark. Be sure to record other observations, especially any differences between the seedlings grown in the light and those grown in the dark. These observations may help you explain the data on numbers of germinated seeds.

Analyzing data

Compare results with the other students who did this Investigation. Write a short report for classmates who did not do this Investigation. Include the hypotheses you tested. Also include your data, your analysis of the data, and any new questions that you thought of.

1. Did any kind of seed germinate better in the dark? in the light? If so, what inferences can you make about where the seeds should be planted?
2. Why were the seeds in the dark not observed until the last day of the experiment?
3. You have observed the effect of total darkness and total light on seeds. Does your data tell you the best light conditions for germination?
4. Do you think some seeds might need both light and dark? How could you test this?
5. Were seedlings grown in the dark different from those grown in the light?
6. You have no data to show <u>when</u> the seeds in the dark germinated. Try to think of a way you could get this data.

If you have thought of any other experiments to do, write down your plan of action. Check with your teacher before starting.

All students should read and discuss this section.

Seeds for many plants ripen and fall to the ground in late summer. Usually these seeds do not germinate until the next spring. What environmental conditions might keep the seeds dormant all winter? What conditions might make them germinate in the spring? How do the responses of seeds to their environment help the young plants to survive?

Seeds above the ground are exposed to light and do not have to grow up through a layer of soil. Seeds below the ground are protected from light, being eaten by birds, and drastic temperature changes. Whether light is a disadvantage or advantage depends on the kind of seed

What environmental conditions could affect germination above and below the surface of the ground? What are the advantages for seeds that germinate on top of the soil? for seeds that germinate underground? Are there any disadvantages for seeds germinating in each place?

Extend Your View 11-1

The best way to germinate seeds

Can you use experimental data to identify what conditions seeds need to germinate? Collect some seeds from weeds or other plants. Choose seeds you have not yet tested. You could bring seeds from home, for example, from vegetables. These seeds should be fresh. They should have ripened during the last growing season. Older seeds may have lost their ability to germinate. If you cannot supply your own seeds, your teacher will give you some.

What environmental conditions do the seeds need to sprout? Find the effect of <u>one</u> variable that you have not tested previously. You will need to design an experiment. Discuss your plan with your teacher before you begin.

You can suggest using seeds from fruits, wild plants (especially weeds in lawns or vacant lots), shrubs and trees, and flower and vegetable gardens. Provide fresh seeds for students who do not supply their own. Students should not know the germination requirements of the seeds. Each pair of students should decide how many seeds are needed.

Someone might try germinating seeds obtained from a ripe fruit in its natural juice. Tomato seeds usually do not germinate in the fruit or in tomato juice, but will germinate on moist paper or in soil.

What conditions did this coconut need to germinate? Are these conditions found on this beach?





12

The water needs of plants

After you complete these Investigations, you will be able to

1. identify some variables that affect water loss in plants.

Plants, like animals, respond to changes in their environment. Animals can move around to find a suitable environment. Most plants cannot. Therefore, plants must adapt in other ways. For example, plants need nitrogen. But some plants grow in soils where the amount of nitrogen is small. These plants get their nitrogen from eating insects.

A venus flytrap resembles a steel trap. When a victim walks over the ends of the plant's leaves, sense receptors are stimulated. In response, the halves of the leaves spring shut. The rims of the trumpet plant (pitcher plant) are coated with nectar that attracts the insects. The inside walls are covered with downward-pointing hairs, which keep an insect from escaping once it enters the plant. Eventually, the exhausted insect falls to the bottom. In the bottom of both the venus flytrap and the pitcher plant is a liquid that helps digest the insect. The digested insects supply nitrogen that is not in the soil.

All plants need water. In these Investigations, you will find out how some variables affect water loss in plants. You will see how the structure of the plants helps them adapt to different environments.



Investigation 12-1
Why do plants wilt?

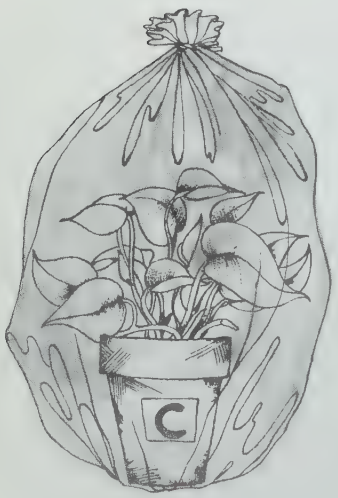
Look at the plant on display in your classroom. This plant was not wilted two days ago. Why do you think it is wilted now? You probably said that the plant needs water. Did the water evaporate from the soil? Or did the plant use up the water? Try this experiment to find out if either of these inferences is correct.

Materials
3 potted plants
2 plastic bags
2 rubber bands
balance
masking tape
marking pen



Gathering data

1. Place a strip of masking tape on each pot. Label the pots A, B, and C. Also mark each pot so you can tell it belongs to your group. Make sure the plant size, the pot size, and the amount of soil are as alike as possible. Water each plant and let it drain.
2. Do not do anything more to Plant A. Put a waterproof plastic bag around the pot of Plant B. Fasten the top of the bag around the bottom of the plant stem as shown. Put Plant C, pot and all, into a plastic bag. Fasten the plastic bag tightly with a rubber band, piece of string, or a wire tie.
3. Use the balance to find the mass of each potted plant. Record the masses, the date, and the time.
4. Set all three plants in a bright part of the classroom, but not in direct sunlight. Write down the questions that you are trying to answer.
5. The next day find the masses of the three plants. Record the date and the time. Write down any other observations you think are important.



Analyzing data

Compare the original masses with the measurements you just made. Are there any differences? If there was a loss of mass, do you think the water was lost from the soil, from the plant, or both?

Investigation 12-2
What environmental variables affect water loss in plants?

Some water taken in by a plant is used in the process of photosynthesis.

A simple device called a **potometer** (poh TAH muhd uh) measures how fast plants take in water. Plants lose water at about the same rate they take it in. So you can use the potometer to infer water losses.

The bubble-potometer works something like the setup you used to measure gas exchange in Investigation 6-2. With that setup, you measured the movement of a drop of liquid in a column of air. With the potometer, you follow the movement of an air bubble in a stream of water.

As a plant loses water from its leaves, it pulls more water into the leaves through the stem from the roots. If a glass tube is substituted for the stem, you can watch the water moving. If you place a bubble in the glass tube, you can measure how fast the water is moving.

The water that enters a plant through the roots returns to the environment through the leaves.



Materials
ring stand, ring, and wire gauze
beaker
boiled water
plastic dishpan or bucket
leafy branches
scissors
paper towel
rubber tubing joined to glass tubing
thin wire
clamp
petroleum jelly
tape
ruler
clock or a watch with second hand

Gathering data

Set up a bubble-potometer with a branch and work with the apparatus yourself before the class does. Allow a class period for the groups to set up and become familiar with the potometer.

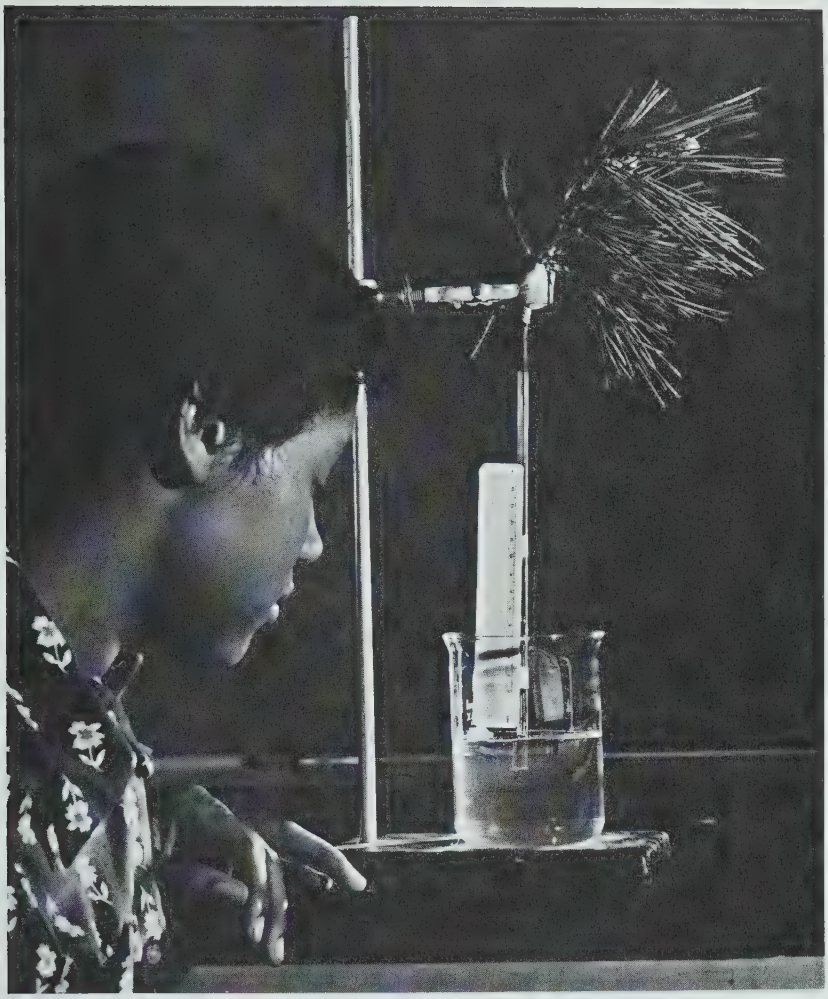
In the first part of this activity, you will learn how to use the bubble-potometer. Then your group can choose a variable and test its effect on water loss in plants. Follow the directions carefully and your potometer will work well.

Unboiled tap water contains dissolved gases that may interfere with the functioning of the plant's transport system.

1. Set up a ring stand and a beaker of boiled water that has been cooled to room temperature. Boiling drives out most of the air from the water. Unwanted bubbles are less likely to form in the tubing.

Warn students not to allow air bubbles into the stem. If pruning shears or a razor blade must be used, trim the ends of the branches yourself.

2. Fill the bucket or dishpan with water. Choose the plant stem to be used. While keeping the end of the stem underwater, cut off about two centimetres of the stem. Do not bring the cut end of the stem out of the water at any time. Try not to wet the leaves of the branch. If you do, blot them dry with paper towels.
3. Now take the rubber and glass tubing and put them completely under the water in the dishpan. Squeeze the rubber tubing to get rid of all the air. Gently slide the rubber tubing over the cut end of the stem. The tubing should fit snugly around the stem. Try not to tear the outside covering, or bark, of the stem. A piece of thin wire may be tightened around the tubing for an airtight fit. Leave the plant and the connected tubing in the water.
4. Place your finger over the open end of the glass tubing. Gently move the branch and tubing to the ring stand. Place the end of the glass tubing in the beaker about one centimetre below the surface of the water. Tighten the clamp over the



stem so the plant is held firmly. You may need to wrap a paper towel around the stem to make it fit the clamp. Put petroleum jelly around both ends of the rubber tubing. This will help prevent leaks.

5. Tape a ruler to the glass tubing. The lower end of the ruler should be near the surface of the water. The ruler allows you to measure the distance the bubble travels. Wait about ten minutes before the next step.
6. Tip the beaker of water, or raise the clamp holding the branch, until the end of the glass tubing is just out of the water. Leave the tubing out of the water until you see an air bubble start to form in the end of the tubing. Then put the end of the tubing back in the water. When you have put the tubing back, you are ready to begin taking measurements.
7. Make measurements at regular intervals such as 30 seconds or every minute. Make a table to record the time and the

The first measurements can be taken as a demonstration for the class.

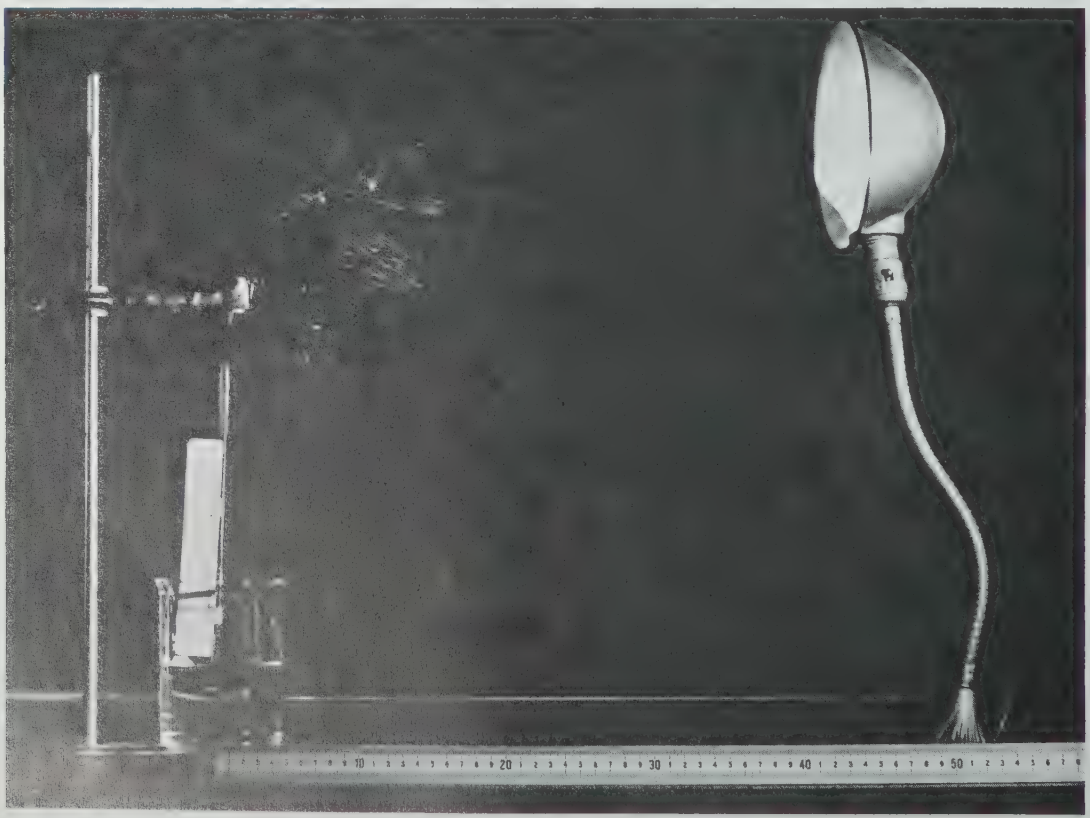
distance the bubble moves. If the bubble has moved almost to the rubber tubing, stop the bubble by gently pinching the rubber tubing. This pushes the bubble down the tubing. Keep the tubing in the water.

8. Record the average of several readings on your data-table.

Now you know how to measure the rate of water loss from a plant. You have data on how fast one plant takes in and loses water. What were the environmental conditions in your classroom? For example, what was the temperature? the humidity? Was there a breeze in the room? Was the branch in bright light, shade, or direct sunlight?

What will happen if you change one of the variables? Will it affect the rate at which the plant takes up and loses water? Decide with the other members of your group which variable you would like to test. Write up your experimental design and discuss it with your teacher before you begin.

These suggestions may help you set up your experiment. You can vary light intensity by moving a light source toward the potometer. For example, you might start with the light 2 m away and move it 25 cm closer each time. Give the plant five minutes



to adjust to each new intensity before you make measurements. Record the distance of the light source or measure the amount of light with a photographic light meter. A fluorescent light is cooler than an ordinary bulb. It is less likely to overheat the plant.

You can change air movement from a light breeze to a strong wind by using an electric fan. For changing temperature, room radiators or heating tape are safe sources of heat. To change the humidity, cover the plant with a plastic bag. For a humid environment, you can put wet sponges or containers of water under the plastic. For a dry environment, you can add chemicals that dry the air.

The temperature will vary with the distance from the radiator. Heat can also be provided by the incubators used in Investigation 11-2.

Students can tape humidity paper to the inside of the plastic bag near the plant during their experiments.

Keep a careful record of your data and your conclusions. You should record how changing each factor affects the uptake of water. Each group will report its findings to the class. On page 145 there is a sample chart for recording this kind of data. In this case "Breeze" was the *if-variable.* Make your own tables to record the conditions during your experiment.





(top) organ pipe cactus
(bottom right) echeveria crassulaceae
(bottom left) orchid

The plants in the top and bottom right photographs store water in their fleshy parts. The plant in the bottom left photograph can absorb moisture from the air through its air roots.





Plant: Coleus *Condition: healthy* *Number of leaves: 16*	*Humidity: 35%* *Temperature: 22°C* *Light: bright*
Breeze	*Rate of water movement*
slow	–
medium	–
fast	–

Analyzing data

Talk with other groups about their data. Think of a way to put the group data on the chalkboard so everyone can understand it. See if the class can agree on how each factor affected water loss. In what kind of environment would plants tend to lose water fastest? In what season in your area do you think plants lose the most water? the least? How could you find out?

Investigating problems usually raises new questions. You may want to set up another experiment to get data on a new question. Write down your hypothesis. Then discuss your idea with your teacher.

Investigation 12-3
Does the number of leaves affect water loss?

Does the number of leaves on a plant affect how fast it loses water? You can easily gather data to answer this question. All you need is your potometer and a branch from a plant. The branch can be a new one or one used in Investigation 12-2. Try to use a branch with leaves of about the same size.

Water loss is more precisely related to leaf area. For simplicity, only the number of leaves is considered with an attempt to keep leaf size equal. The general relationship should be apparent.

Materials
potometer
boiled water
branch

If the container of boiled water has bubbles on its sides, reboil the water.

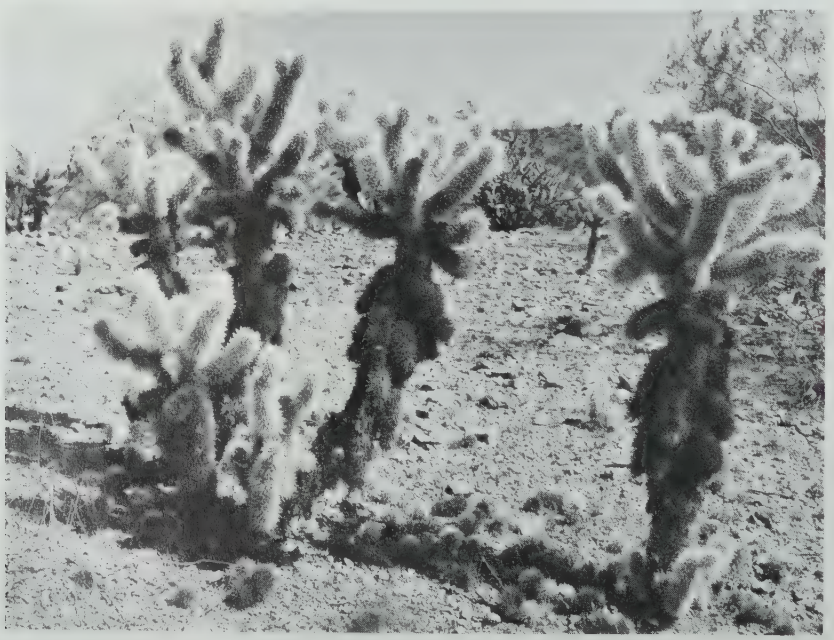
Gathering data

An easy way to answer this question is to measure water flow through a branch as you decrease the number of leaves. You already know how to set up the potometer, but read over these hints before you start. Once you cut off leaves, you cannot replace them. So plan your steps carefully.



oak

cholla



1. Try to make measurements with at least five different numbers of leaves.
2. Set up your experiment using conditions that will give the largest water loss. That way it will be easier to measure differences in the rate of water loss.
3. Keep a careful record of your data. When you are through, plot the data on a graph. Show the number of leaves left on the branch on the horizontal axis. Put the rate of water loss on the vertical axis.

Analyzing data

1. When you removed leaves you were reducing the total leaf area of the plant. Compare your data with that of other groups. Can you make a general statement about how leaf area affects water uptake and water loss in plants?
2. In what kind of environment might fewer leaves be an advantage to a plant? a disadvantage?
3. How could the size of leaves affect water loss?

Extend Your View 12-1
Adapting to climate

Can you identify some variables that affect water loss in plants? These are photographs of a cholla (CHOY uh) and an oak. Infer what environment each plant lives in. Which of these plants is more likely to live in an area of low rainfall? Winter is a dry season for plants. How does the oak tree control water loss in winter?



Unit THREE

Living things affect each other



13

Coyotes and their prey

After you complete this Investigation, you will be able to

1. predict what happens when a food web is disturbed.
2. evaluate a proposed solution to an environmental problem by considering the needs of the organisms involved.

The coyote looks like a small wolf. The map on page 152 shows that coyotes are found in many parts of North America. They are very **adaptable.** This means that coyotes can change their habits to fit into many environments. Coyote dens have been found underground, in hollow trees, in rocky caves, or even next to houses and highways.

Coyotes have been a native of North America for many centuries. They are mentioned in Indian legends and in the reports of the early explorers. The coyote has a reputation as a shrewd animal.

When the homesteaders moved west, they plowed the fields, fenced off some of the land, and brought in sheep and cattle. They caused many changes in the environment. Some people claimed that the coyotes also caused problems. The sheep ranchers, in particular, said that the coyotes killed many of their animals.

For many years, the government helped the sheep ranchers and farmers control the coyotes. They set out traps and poisons to reduce the number of coyotes. Recently they even hunted coyotes from airplanes. Now people from all parts of the country are concerned about the coyote problem.

Investigation 13-1
The coyote problem

None of the information given in the letters is false. However, there will be discrepancies of interpretation between authors. For example, there is lack of agreement on the danger of 1080 to the environment or the cause of the sheep ranchers' economic problems.

In this Investigation, there are five letters similar to ones written to members of the United States Congress. Each one describes one person's view of the way the coyote problem should be handled. The letters were written because the United States Congress was going to vote on a law that would change the way coyotes would be controlled.

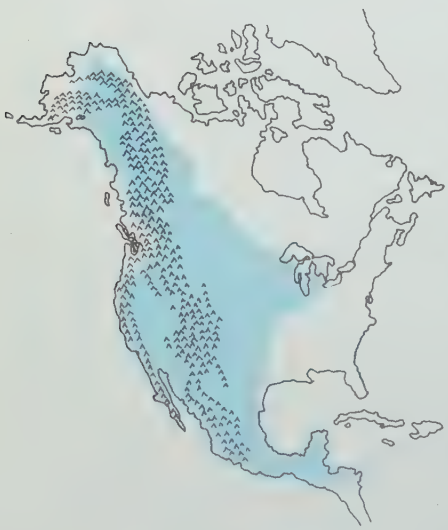
Gathering data

The first letter is from a scientist. Everyone in the class will read it. Then the class will divide into four groups. Each group will read one of the four remaining letters. Your class will discuss the different perceptions of the problem and decide if the proposed law should be passed.

Letter 1, from a scientist

The coyote problem is complex and you will need some background information. In a laboratory or classroom you can isolate one organism and study it by itself. But in nature organisms never live alone. They interact with many other organisms. All the organisms that share the same environment form a **biological community.**

The areas where most coyotes live have been shaded blue on this map. Are there any coyotes where you live?



Each kind of organism in a community is a link in a **food chain.** A green plant absorbs energy from the sun. Some of this energy is used to keep the plant alive. Some of the energy is stored as carbohydrates. When an animal eats a plant, the stored energy is passed on. The plant and the animal are links in a food chain.

Usually, organisms are part of more than one food chain. For example, in a pond community, turtles eat both plants and small fish, such as minnows. And mosquitoes feed on fish, frogs, and people. A group of connected food chains is called a **food web.**

The coyote interacts with many organisms in its environment. Here is a food web that includes the coyote. The arrows show what each organism eats. Rabbits eat grass and vegetables. Then coyotes may eat these rabbits. Some of the energy that rabbits gain from eating grass and vegetables is passed on to the coyotes.



These are some of the animals in the coyote's food web.



coyote



meadow mouse



cottontail rabbit



white-tailed deer

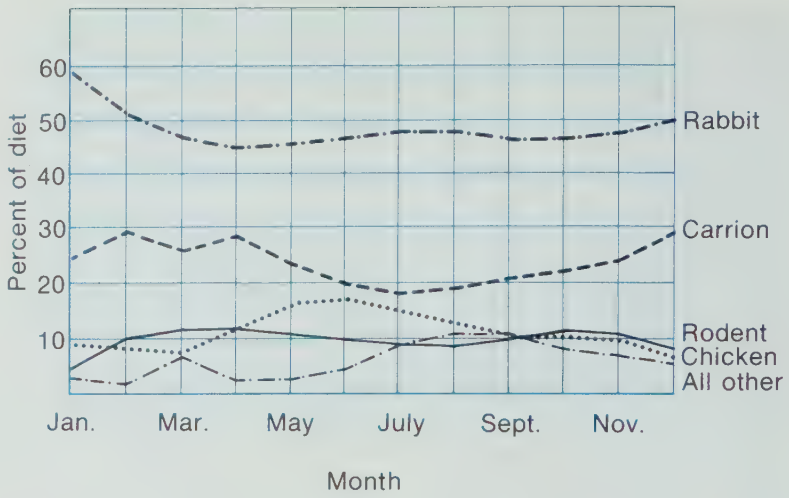


sheep



cattle

Rabbits are not classified as rodents. "Rodents" includes rats, mice, and other small, wild animals. "Chicken" includes all poultry, whether freshly killed by coyotes or picked up dead. "All other" includes fruits, grains, insects, and snakes. In this study, "Carrion" includes all livestock, no matter how acquired, plus other decaying meat. True carrion from coyotes' stomachs would show obvious signs of bacterial decay, hardening (as with hides), or maggot infestation.



This graph shows the coyote's diet for one year.

Scientists at the Kansas Agricultural Experiment Station studied what coyotes eat. It is difficult to observe coyote behavior because they hunt and eat mainly at night. The scientists analyzed the food in the stomachs of 1600 coyotes killed by hunters.

This graph shows their data for one year. The bands on the graph show the percent of different types of food in the coyote's diet. Notice that the bands on the graph swell and shrink. Coyotes usually eat what is plentiful. The supply of each kind of food changes during the year.

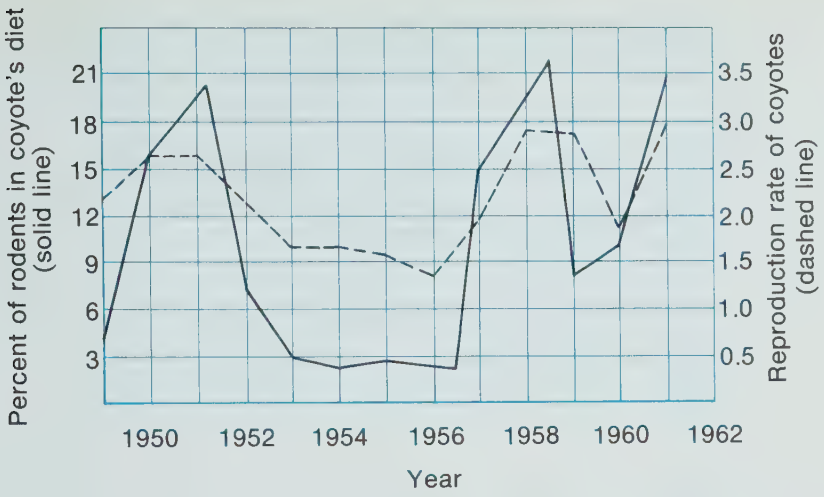
Rabbits and rodents also carry ticks, lice, and other vermin that are a source of disease for both people and domestic animals.

The data shows that almost two-thirds of the coyote's diet is rabbits and rodents. These animals eat the grain and grass that the ranchers' cattle and sheep eat. They are considered pests by farmers and ranchers. Rabbits and rodents are difficult and expensive to control.

Carrion is the decaying flesh of dead animals, including livestock. Coyotes often find the dead animals and livestock on the range. They will also eat dead farm animals that have not been buried. Most of the meat from livestock found in coyote stomachs was decaying before the coyote ate it. Fresh livestock seems to be a very small portion of most coyotes' diet.

A small number of coyotes do eat mainly fresh livestock. They are called "killer" coyotes. Often killer coyotes are handicapped. For example, they may have lost one or more legs in traps. These losses make it difficult for such coyotes to catch rodents and rabbits. So they attack sheep, which are easier to catch.

Coyotes are important in controlling the populations of rabbits and rodents. There is a natural balance between the rodent



This graph shows how the populations of coyotes and rodents are connected.

population and coyote population. This graph shows how the coyote population increases when there are more rodents. If coyotes were eliminated, the rodents could increase and disrupt the food web.

You can infer from the data that the coyote population changes to fit the food supply. Adjustment takes no more than one year. Coyotes might have been a pest in 1952 and 1959, since the coyote population was still high while the rodent population was dropping. Perhaps 1953–1957 were not bad because coyote populations were low, too. Other data indicates that coyote population size is only one of many variables related to livestock losses.

For example, in 1946, the ranchers who owned property around the National Bison Refuge in western Montana asked the United States government to destroy the coyotes inside the refuge. They claimed that coyotes used the protected area for breeding; then moved out to the ranchers' land and killed livestock. The government began trapping and poisoning the coyotes. Almost all the coyotes inside the refuge were killed.

After the number of coyotes decreased, the rodent population grew rapidly. The rodents became serious competitors for the grass the bison ate. The bison were in danger of starving. Half the bison had to be killed so the remaining bison would have enough food. Trapping and poisoning of coyotes was stopped. The coyote population increased. There were fewer rodents and the bisons had enough grass to eat.

You asked about the poison "1080" and its effects. It is usually injected into meat that is left as bait for coyotes. It is a very potent poison, especially to coyotes and dogs. It can kill other animals including people and there is no known antidote. Table 13-1 (page 158) gives some data on 1080.

1080 is a commonly used trade name for sodium fluoroacetate. 1080 does not degrade as quickly as other commonly-used poisons. The flesh of an animal killed by 1080 serves as a poison-station for other animals. If 1080 enters a food web, it can be an indicator of energy transfer.

Animals that usually eat carrion, such as coyotes and rodents, may eat poisoned bait. If the bait contains 1080, the animal eating it may die. In some areas certain kinds of animal have been wiped out by poison and other methods of predator-control. The black-footed ferret, for example, is now considered an "endangered species." This means that if it is not protected,

In the law this Investigation is based on, the term "predatory animal" is defined as any mammal or reptile that habitually preys upon other animals. Your students may want to develop a less limited definition.

Table 13-1 *Data on 1080*

Animal	Lethal dose of treated bait (grams)
coyote	40
dog (domestic)	40
cat (domestic)	10
fox	45
bobcat	185
prairie dog	35
bear	3850
mink	40
marten	40
magpie	7
badger	370
human	3850
raccoon	615
golden eagle	640
chicken	360
hawk	320
great horned owl	450
black vulture	115
opossum	6170

Students could collect information on other endangered species such as the grizzly bear and the lynx.

this kind of animal may become extinct. The eagle, too, is endangered.

I hope this information will help you decide how to vote on the proposed bill.

Letter 2, from a sheep rancher

You will be voting on a law that will change the coyote-control program in my area. I'm writing to tell you how bad the problem has become.

Since a ban on poisons was in effect in 1972, these figures supposedly reflect a year without poisons. It is not essential that students know this until the end of the investigation when they hypothesize about the effect of a ban on poisons.

I'm one of many sheep ranchers in this valley. We had a meeting last week to discuss our problems with government officials that are supposed to help us. Each year we all lose sheep to the coyotes. This table shows how many sheep were lost in four states during 1971 and 1972.

Many misconceptions have contributed to a hatred of the coyote. This rancher assumes, because there were teeth marks present, that the coyote killed the sheep. It is also possible that the sheep died on the range and the coyote ate it as carrion.

Last week I lost six sheep in one night. I found them with coyote teeth marks on them. The coyotes only ate part of the sheep. They seem to kill for the sake of killing. That's one reason why we hate coyotes. We work hard to raise our sheep, and then coyotes kill them.

Table 13-2 *Sheep lost to coyotes*

Region	1971		1972	
	Number	Value	Number	Value
Idaho	1635	$48 050	1843	$55 280
Montana	1444	$43 320	2036	$64 090
Nevada	667	$20 010	819	$24 570
Oregon	1555	$46 650	1502	$45 060
Total	5301	$158 030	6200	$189 000

I called the government men to set out poison for the coyotes but they didn't put enough out. I lost three more sheep since then. So I'm going to put out my own poison. Some people say that poisons are killing other wildlife too, such as bobcats, mountain lions, bears, ferrets, and badgers. Some of these animals might eat the poison, but mostly the coyotes do.

If the law passes, it will be the end of sheep ranching. Right now I lose about eight percent of my sheep to coyotes. If they aren't controlled, I'll lose even more, and I won't be able to stay in business. If we lose more sheep, then there will be less lamb for people to eat and less wool to make clothing. With such a shortage, lamb and wool will get so expensive that no one will be able to afford them.

I know there are a lot of people who don't like anyone killing coyotes. I wish there was another way. But I don't like coyotes killing sheep. Even if the bill passes, I know there will be many ranchers getting poison and doing their own coyote-controlling.

The complaint by sheep ranchers that they will go out of business is not uncommon. The letter from the conservationist offers some other explanations for the sheep ranchers' economic plight. The real explanation may be a combination of factors.

Letter 3, from a conservationist

I am a member of the Western Conservation Club. Our club wants to preserve the environment. I want to explain our position on the proposed law restricting the use of poisons for controlling coyotes and other predators.

I have nothing against sheep ranchers. On many issues we share similar positions. We are both working to keep strip mining and industrial development from ruining the area. But sheep ranchers want to use poisons and other methods to control coyotes. We are against this.

In 1900, before any control programs, there were over 50 million sheep in this country. Today, after nearly 70 years of poisoning, shooting, and trapping coyotes, there are only 16

million sheep on the ranches. Efforts to control coyotes have not helped the ranchers because coyotes are not the main problem. The main problem is economic.

Wool prices were higher 50 years ago. Other fabrics are now preferred by many people. Prices for sheep have dropped over 30 percent in the last 20 years. In addition, ranchers' expenses have increased nearly five times during this period. The coyotes have not caused these problems. But it is easier to kill coyotes than to kill increasing expenses and competing industries.

The effort to control coyotes has not only failed to help sheep ranchers, but also has created other serious problems. I don't think sheep ranchers understand that coyotes eat large numbers of rabbits and rodents. When coyote populations decrease, populations of rabbits and rodents can increase. Rabbits eat mainly grass. When there are too many rabbits, livestock have a hard time getting enough grass to eat. Rodents eat grain that has been stored; so an increase in rodents also costs the ranchers money.

Another problem is raised from 1080, a poison used to kill coyotes. No one knows how many animals have been killed by eating poisoned bait set out for coyotes. Most ranchers have had at least one dog poisoned by it. Probably hundreds of mountain lions, badgers, eagles, hawks, and other predatory animals have been killed too. When it rains, some of the poison from the bait may dissolve and be carried to water supplies. No one knows just how long 1080 remains dangerous after being spread around.

I urge you to vote for the proposed law to change the control of predatory animals. It might encourage the development of newer herding methods to decrease losses. We should help the sheep ranchers. We need our sheep ranchers and the wool and lamb they provide. They need laws to help them in their battle to survive. Killing coyotes has not helped them. So let's try a new approach.

Letter 4, from a trapper

I am writing to you because I am concerned about the proposed changes in the coyote-control law. I have worked for the U.S. Fish and Wildlife Service for the past 15 years. One of my main duties is to kill coyotes when a sheep rancher requests help. I don't enjoy killing coyotes, but I see the need for it.

In my territory, there used to be 35 sheep ranchers. Now there are only 17. The rest of them left or switched to raising cattle.

Table 13-3 *Coyotes killed by government*

Year	Number	Year	Number
1937	80 299	1955	55 204
1938	84 844	1956	55 402
1939	98 039	1957	62 585
1940	104 072	1958	62 765
1941	110 495	1959	78 714
1942	111 076	1960	94 769
1943	103 971	1961	100 363
1944	108 050	1962	104 787
1945	102 979	1963	89 653
1946	108 311	1964	97 096
1947	103 982	1965	90 236
1948	90 270	1966	77 258
1949	75 448	1967	75 892
1950	66 281	1968	69 390
1951	60 455	1969	74 070
1952	50 661	1970	73 093
1953	55 000	1971	75 661
1954	52 636		

Why? The profits from raising sheep have been decreasing steadily. The ranchers blame coyotes for killing their lambs. They see the coyote as their number one enemy. I might hate coyotes too, if I thought they were costing me money.

The ranchers depend on trappers to protect their sheep. Let me explain a few things about the methods we use. Coyote "getters" are now illegal, but some people still use them. A getter looks like a pipe that is partly sticking out of the ground. A little bait is put on the tip of the getter. When a coyote starts to take the bait, the getter explodes and sprays out poison. If the explosion doesn't kill the coyote, the poison will. We tried getters for a while but there were some accidents. So they were outlawed.

Coyote getters are often referred to as M-44's. They are a more selective means of killing coyotes because the device is baited with coyote urine or other substances that attract the coyotes. M-44's can only be used by authorized persons and the site must be appropriately marked with warning signs.

We sometimes shoot coyotes from airplanes and helicopters. But this is pretty expensive. Since coyotes often come out at night, it's hard to spot them from the air.

We do quite a bit of trapping, but I don't like this method because other kinds of animals also get caught. Often a coyote just gets injured in a trap. Injured coyotes cannot run fast enough to catch rabbits and rodents; so they eat lambs which cannot run fast. They become "killer" coyotes. Trapping just makes more problems for the rancher.

I think poisoning is the best method to get rid of the coyotes. We set out rabbit or sheep meat with 1080 in it. This poison

kills the coyote in a hurry. True, 1080 can kill some other animals too, including dogs, if they eat the poisoned bait. But the little bit of poison in the body of a dead coyote won't hurt a cougar or other animal that eats the remains. So I don't see how the poison we use really hurts the environment. Sometimes coyotes avoid the poisoned bait, maybe because they spot other poisoned animals in the area.

I won't take any more of your time. I did want you to know that I think outlawing poisons would be a mistake. Right now I think we trappers are doing a pretty good job. We haven't caused any animals, including coyotes, to become extinct, and we do try to run a sensible control program. If you vote to outlaw poisons, you might encourage sheep ranchers to break the law. They will do their own poisoning, and may try to wipe out all the coyotes. I don't want to see this happen.

Letter 5, from a cattle rancher

Coyotes do not pose as big a threat to cattle ranchers as to sheep ranchers. Many sheep ranchers feel the cattle ranchers' problems are reduced by the coyote control programs, especially in areas where both sheep and cattle are raised. Ask students if there could be any other reason for the cattle ranchers' limited problem with coyotes. Maybe coyotes choose to attack the smaller of the two species.

I read in the paper the other day that there is a new law being considered to restrict the poisoning of coyotes. As a cattle rancher, I'm totally in favor of this law. At one time I thought that killing off the coyote was a sensible thing to do. I've since changed my mind.

First, I've seen how some sheep ranchers hate coyotes. The way they talk about these animals makes my blood boil. They say "The only good coyote is a dead coyote." For a while I agreed because coyotes did kill a lot of their lambs. But killing all those coyotes hasn't helped much. Coyotes seem to be smarter than people in some ways. They'd have to be in order to survive.

The government trappers that I've met agree with the sheep ranchers. But the trappers know that if they kill all the coyotes, they will not have a job. They have convinced the sheep ranchers that killing coyotes is the only way to handle the problem. So they go around spreading poison, trapping, and shooting coyotes. You would think sooner or later they would admit that they are not solving the problem.

Now I also realize that killing coyotes affects my cattle business. Coyotes eat a lot of rodents and rabbits. When there are fewer coyotes, the number of gophers and rats increases. The rodents eat a lot of the grain I store for my cattle. Rabbits eat a lot of the grass my cattle need for grazing. Coyotes kill a few of my calves, but I figure that's a small price to pay for keeping the rodents and rabbits from eating my grain and grass.

Then there is the problem of poisons and traps all over the range. I lost two dogs in the last three years. I tracked both of them in the snow and found them dead not far from some poisoned meat that was meant to kill coyotes. Luckily I found the dogs and buried them before some cougars got killed from eating the poisoned dogs.

See why all this coyote-killing really makes me angry. It's doing a lot more harm than good. There has to be a better way to control coyotes and other predators. I'm looking to you and other lawmakers to come up with something. If I can do anything to help, let me know.

The proposed law

Here are the three main parts of the law referred to in the letters.

A. Money will be provided for research to find more humane methods for controlling predatory animals. This might include a coyote-repellant for sheep and better herding techniques to reduce losses.
B. Poisons cannot be used unless there is an emergency: the health and safety of humans is threatened; a species of animal is endangered; there is serious damage to livestock.
C. Ranchers will be paid current market value for livestock lost to coyotes or other predators.

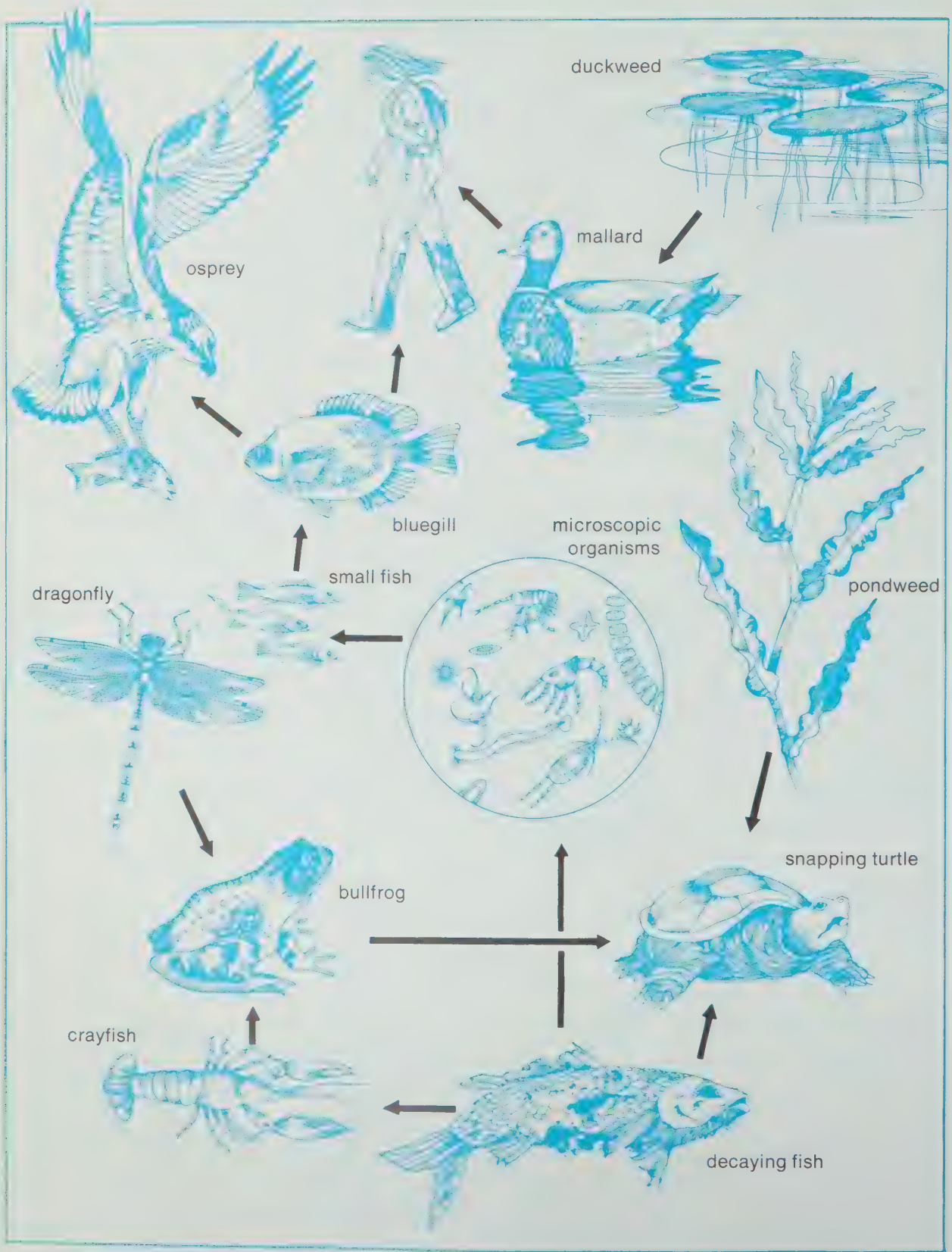
Skunk spray and the urine of mountain lions have both been used as repellants.

Analyzing data

1. Do you think the law should be passed?
2. Would this law solve the coyote problem?
3. What problems could such a law bring?
4. How could you improve this law?

Extend Your View 13-1
Managing a lake

Can you predict what happens when a food web is disturbed? Paul and Linda Jackson just bought Round Lake. The lake does not contain any large fish. But there are some medium-sized fish, such as bluegills and perch. Around the lake shore there are cottages and boats to rent. A store sells bait and food to the vacationers.


duckweed
mallard
osprey
bluegill
microscopic organisms
small fish
dragonfly
pondweed
snapping turtle
bullfrog
crayfish
decaying fish

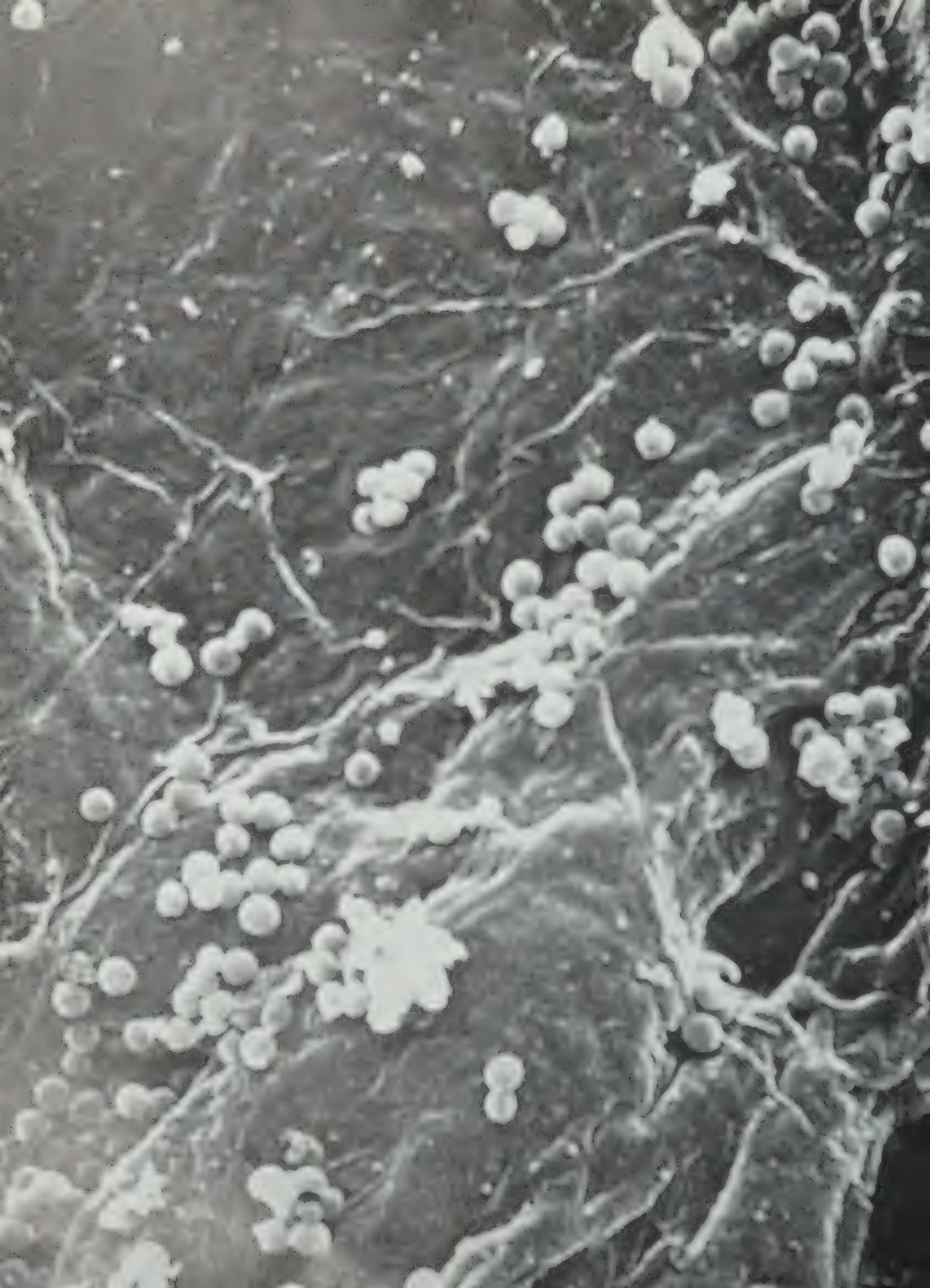
The Jacksons want to attract more people who fish. They decided to add new kinds of fish that grow to a large size and are exciting to catch. Here is the food web that existed in Round Lake when the Jacksons bought the property.

The Jacksons assume that the lake will support as many medium-sized fish as before, plus many new sport fish. They think more people will want to fish in Round Lake. They think that vacationers who previously came to fish for the medium-sized fish will still be satisfied, and will continue to come. What do you think will happen? Write a statement to the Jacksons. Tell them if their plan is likely to work. Give reasons to support your position.

Extend Your View 13-2
An experiment with coyotes

Can you evaluate a proposed solution to an environmental problem by considering the needs of the organisms involved? Scientists have found that they can teach an animal not to eat certain foods. First they give the animal food treated with a chemical. The food makes the animal sick. The next time the animal is offered the food, the animal refuses to eat.

This technique was tried in the laboratory with coyotes. A few coyotes were given lamb meat treated with a chemical. After the coyotes got sick, they refused to eat lamb meat. They also would not attack lambs. The coyotes' behavior could be changed for as long as six weeks. After six weeks, the coyotes would attack lambs again. If this technique was used outside the laboratory, would it solve the ranchers' problem? How would it affect other organisms?



14

Competing with microorganisms

After you complete these Investigations, you will be able to

1. recognize some signs of decay.
2. identify conditions that inhibit the growth of microorganisms.
3. predict the desirable and undesirable effects of preserving food.

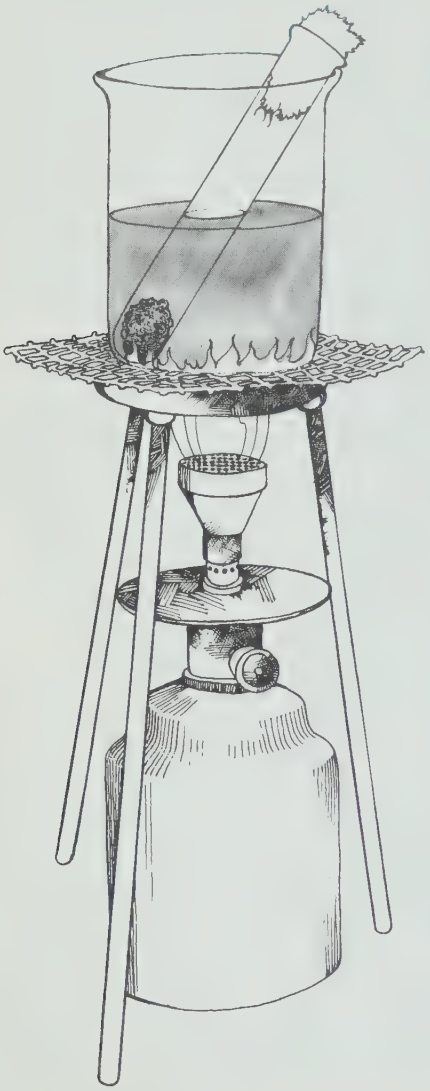
Organisms that live in the same environment interact with one another. The interaction can be helpful or harmful. Often the interaction occurs as organisms compete for food and living space.

People's most common competitors are microorganisms. **Microorganisms** are small organisms, so small that individuals can be seen only with a microscope. Bacteria, molds, yeasts, and algae are a few microorganisms that may be familiar to you. The photograph shows the skin of a guinea pig, magnified many times. The round objects are *Staphlococcus* bacteria.

Microorganisms live in almost every type of environment. Some are able to move; others cannot. In Investigation 10-1 you looked at euglenas. Euglenas are microorganisms that move and carry on both photosynthesis and respiration. Other microorganisms carry on only respiration. Some microorganisms can even live without using any oxygen.

Some microorganisms are able to metabolize in the absence of oxygen. These organisms are called "anaerobic." Those needing oxygen are called "aerobic."

The fermentation of sugar into ethyl alcohol is carried out by anaerobic yeast cells. The deadly disease botulism is caused by the anaerobic organism *Clostridium botulinum*, which can exist in vacuum cans and jars of food.



Caution: To avoid accidents make sure that water baths are steady and not near the edge of a table. To save time, you may wish to set up the water baths around the room at a few safe locations. Do not state what the boiling is supposed to accomplish.

Investigation 14-1
Why does food spoil?

Have you ever tasted soured milk or cracked open a rotten egg? Some foods, such as sugar, can be stored for months without spoiling. Other foods, such as vegetables, can spoil in a few days, especially if they are stored in the wrong place. Doing this Investigation should help you understand why food spoils.

Materials

fresh hamburger
2 test tubes with cotton plugs
test tube rack
distilled water
test tube holder
beaker
stand and wire gauze
burner
marking pencil
microscope
3 microscope slides
3 cover slips
medicine dropper or wire loop

Gathering data

Take two pieces of hamburger, each about one cubic centimetre. Put each piece of hamburger into a separate test tube. Shape the pieces so that they can slide easily to the bottom of each tube. Then fill each tube half full with distilled water. Plug the tubes with cotton and label them A and B.

Place Tube B in boiling water for 15 minutes. Then remove the hot tube with a test tube holder. Place both tubes in the same test tube rack in a warm place. Label the rack so you can identify it later.

Observe the appearance of the meat and the liquid in each tube every day for three days. Look for the production of gas bubbles or changes in color, texture, or odor. On the third day, remove the plugs to make your final observations.

Use the technique you learned in Appendix D to make a separate wet mount of a drop of water from each tube. Observe each drop carefully under the high power of the microscope. It may help to reduce the amount of light. Do both drops look the same? Observe a drop of distilled water for comparison. Draw or describe in words any differences you can see under the microscope.

Students should be able to see large numbers of microorganisms in the unpreserved food. The preserved (boiled) food will probably have low bacterial counts. Mold, however, may have developed if the tubes were not plugged quickly.

Analyzing data

1. The hamburger in Tube A has begun to break down, or decay. What are some signs of decay?
2. What inference can you make from your data about why some food spoils?
3. How could you apply what you have learned to food-handling and preparation at home or in restaurants?

Discuss possible sources of contamination of the meat including human handling at many stages (the slaughterhouse, the butcher, and the students themselves). Ground meat provides a greater surface area than a solid piece of meat for bacterial contamination.

Investigation 14-2
Do microorganisms cost you money?

Almost all of the "fresh foods" we eat are picked, dug up, or butchered days before we buy them. In the United States, only 3.8 percent of the people work on farms. Everyone else gets his food shipped in, which takes time. Even farmers go to the store for some of their food.

Data for Canada is divided only into urban and rural populations. The rural population is not subdivided into farming and residential.

A good part of the food farmers and ranchers produce is not grown to be eaten fresh. For example, some food grown in the summer must be stored for winter-eating. Much of the food is processed, or changed, before it gets to the consumer. The food may be frozen and packaged, or boiled and canned. It may even be combined with many other ingredients to make an "instant" meal.

Students generally know that food is treated and packaged in a variety of ways, but may not realize that these processes are intended to reduce contamination and spoilage. Processing, in itself, is no guarantee of unspoiled food. There have been several instances of contaminated canned foods resulting in food poisoning.

Gathering data

The people who manage the grocery store or supermarket in your neighborhood are experts on reducing food spoilage. You will gather data from them on preserving food. No more than four students should go to each store. Pick a time when the store is not very busy. Tell the manager you are doing a project for school on how to preserve food. If the store has a butcher or baker, or any other specialists, try to talk to them, too. Each interview should take about ten minutes.

Here are some questions to help you plan your interviews. You will probably think of other questions to ask.

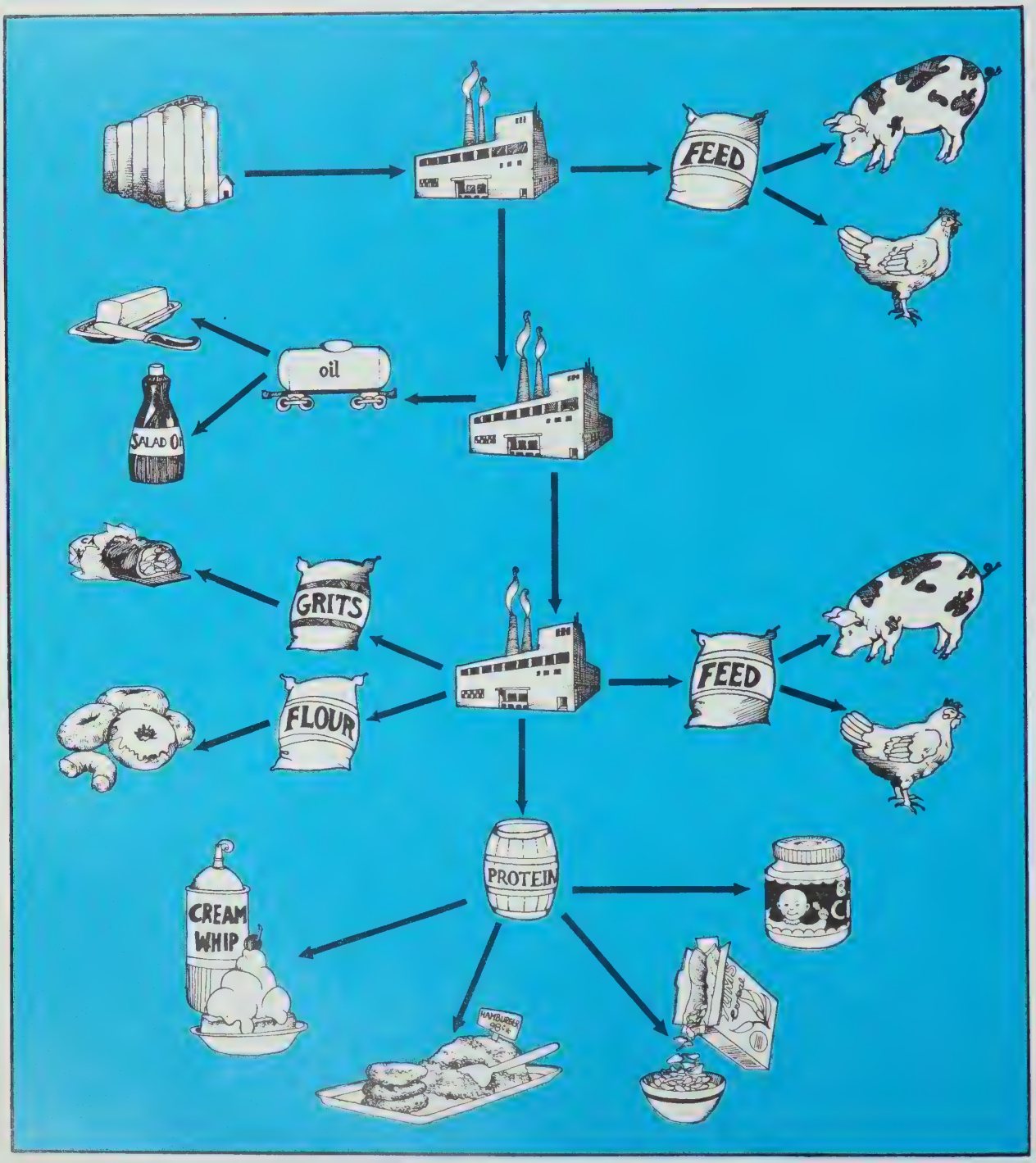
Help the students decide in which stores to make interviews. If the number of local stores is limited, assign one group per store to do the survey and report to the rest of the class. Stores are least busy during midday.

Storekeepers should not get the idea that students have come to inspect their premises for violations of health laws.

Questions for the manager:

1. Which foods can you keep the longest? Which foods have the shortest storage times?
2. What ways are there to reduce the rate at which foods spoil?
3. Is there any law that tells you how long you can keep food in the store and still sell it?

This flow chart shows a few of the edible products that are made from soybeans. The factory symbol stands for a series of steps in the processing of soybeans.



4. Do you ever have to send foods back to the supplier? Why?
5. Do other kinds of food besides fresh vegetables become unusable if they are in the store too long?
6. Do you know how much it costs the store each week to keep food from spoiling? Or how much food has to be thrown out?
7. When food spoils and is thrown out, how is this loss paid for?
8. Which foods last longest: dry foods, canned goods, or frozen foods?

Questions for meat, vegetable, and bakery specialists:

1. How long can you keep meat, vegetables, fruit, or baked goods?
2. Which items do you have to sell right away?
3. What special ways do you have to keep food from spoiling?
4. What are the signs of decay in meat, vegetables, fruit, or baked goods?

If you bite into an apple and put it aside, the part exposed to the air turns brown. This process protects the rest of the apple from drying out and from decay. If the apple is turned into applesauce, it loses its ability to resist decay. The maker of the applesauce often adds substances to keep it from spoiling. These substances are part of a group of substances called food additives.

Some additives, like calcium propionate, prevent the growth of molds. But not all additives are used to protect food from microorganisms. Carbon dioxide is added to drinks to make them bubbly. Other additives are used to change the color of food, to thicken it, or to keep it flowing freely. While you are in the supermarket, collect data on food additives. Check the labels on processed foods. Make a list of the ingredients that you do not recognize, for example, substances like sorbic acid and sodium benzoate.

Flour may be bleached; dried apricots may be treated with sulfur dioxide to preserve the orange color. Syrups may be thickened. Calcium phosphate is often added to salt to keep it flowing.

Also try to compare the prices of fresh foods and processed foods. Which cost more: fresh vegetables, frozen vegetables, or canned vegetables? What variables will you have to control when you make the comparison? See if there is a "natural" foods section in the supermarket. Natural foods are grown and processed without additives. How do the prices of these foods compare to other similar products?

The same food must be compared. Is the quality the same? Quantities must be comparable. One must also consider the value of convenience. Each comparison should be made in one store. Prices and quality vary from store to store.

Pick six of the additives that you found on the labels. Use the library to try and find out the purpose of each additive. Some people in your class may want to write to large companies

that process food. Ask why the suppliers add extra substances to the food. Ask if there are other methods for preserving food that the suppliers could use.

Analyzing data

1. Which kinds of food can be stored longer than others? Does moisture help to preserve food?
2. What are several ways to process foods so they stay edible (can be eaten)?
3. How large is the amount of food that spoils in the store before it can be sold? Who pays for this loss?
4. How does the local grocery store make sure that its customers get unspoiled food?
5. Do you pay extra for processed food?
6. Which costs more: food with additives or "natural" food?
7. How does preserving food affect the competition between microorganisms and people for food? Which methods of food preservation are most effective? least effective?

It is interesting to note that "natural" foods, which have been processed less, are usually more expensive. This may be because they spoil more easily and this cost has to be absorbed by the consumer. Also the volume sold is less and this often means a higher price.

Investigation 14-3
The rate of decay

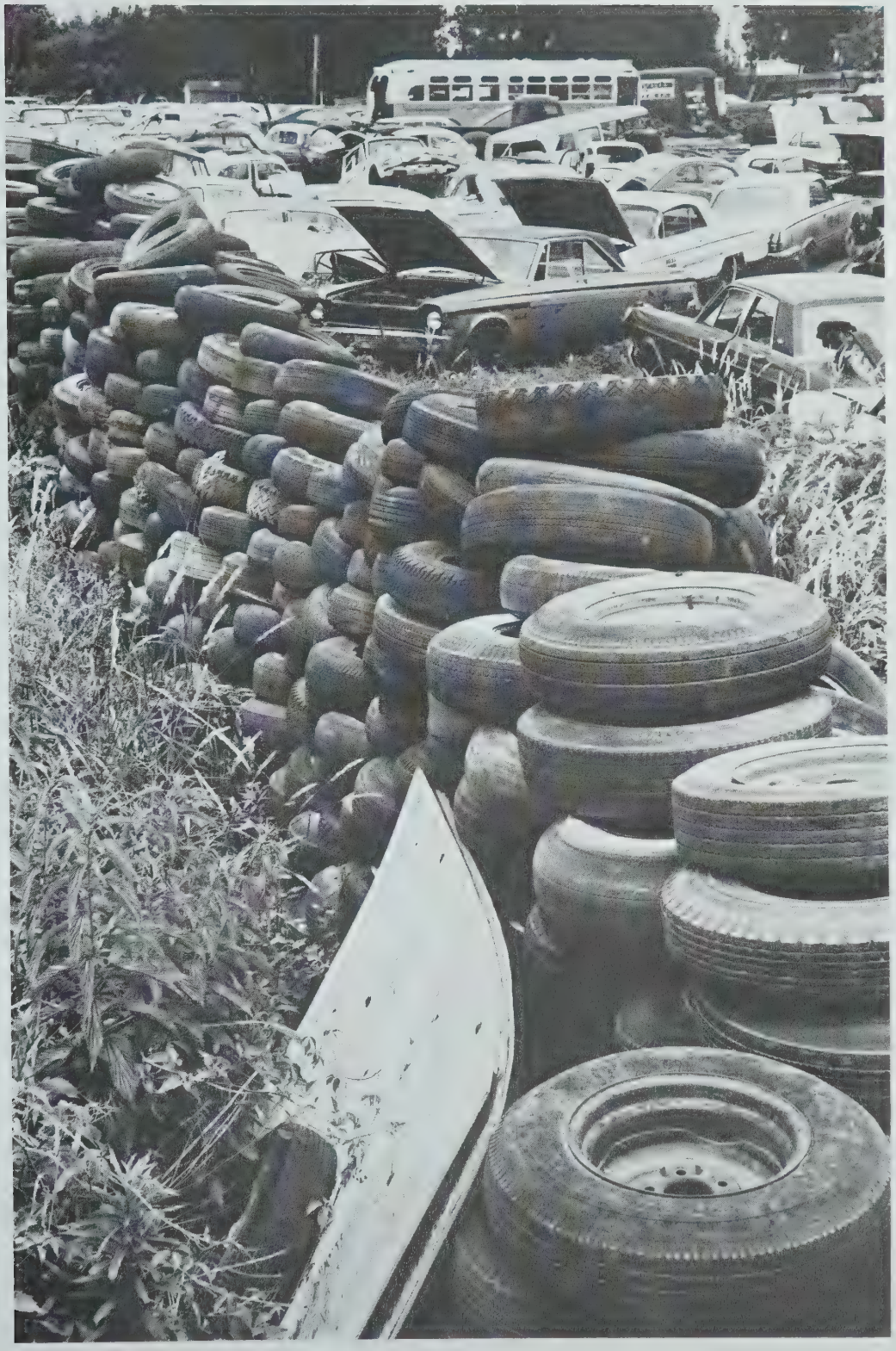
Many communities collect waste materials from their citizens and then dump it in special areas. Everything is dumped, from newspapers, to old toys, to junked cars. Then a bulldozer covers the waste with dirt. As the world population grows larger, people produce more and more waste materials. Can people keep on using dumps?

Gathering data

Food webs allow energy, in the form of food, to flow from one organism to another. Every organism is a food source for some other organism. An organism is made of complex substances. When an organism dies, microorganisms break down the complex substances into simple substances. These simple substances might serve as food for plants if they are left in the soil.

Look at the demonstration your teacher has set up. This garbage was buried in the soil about two weeks ago. Carefully record the condition of each piece of garbage. Compare each piece of garbage to the fresh samples. The garbage in the container looked like the fresh samples two weeks ago.

What happens to discarded cars and tires in your area?



Emphasize that different materials decay at different rates. Preventing microorganisms from decomposing organic materials interrupts the energy flow through food webs.

Introduce the environmental issue by asking what would happen if more and more synthetic, nonbiodegradable products are made.

Analyzing data

1. Which materials did not seem to change? Which of the materials changed? Which materials changed the most? Which changed the least?
2. What are the benefits of preventing decay by the use of preservatives? What are the drawbacks? What would happen if none of our waste could decay?

Extend Your View 14-1
A bulging can on the shelf

Can you recognize some signs of decay? Suppose you are helping a friend shop for groceries. Your friend picks up a can of prepared beef chili. The can is bulging and swelled up at both ends. What could cause the can to bulge? What advice would you give your friend about buying the chili? What reasons would you give for your advice?

Extend Your View 14-2
The woolly mammoth

Can you identify conditions that inhibit the growth of microorganisms? In 1806 a scientist in Siberia dug the body of a woolly mammoth out of the frozen ground. Meat from this 50 000-year-old animal was eaten by people and dogs. Make a hypothesis to explain why this mammoth had not decayed after being dead for 50 000 years.

Extend Your View 14-3
A "super-preservative"

Can you predict the desirable and undesirable effects of preserving food? Suppose you are a scientist who discovers a chemical that stops microbes from growing. The chemical is harmless in every other way.

Adding this chemical to foods could increase food supplies by 20 percent. Spraying farmlands would decrease the loss of crops. Would you advise world leaders to use your chemical?

A "complete preservative" might also prevent the digestion of food by the body.



(left) This painting of a woolly mammoth was done about 15 000 years ago in a cave in France. (below) Workers discovered the remains of a 250 000-year old mammoth while doing roadwork in Rome.



15

Organism versus organism

After you complete this Investigation, you will be able to

1. design an experiment to explain an interaction between organisms.
2. infer how substances produced by organisms are related to their survival.

Have you ever wondered why termites eat wood? Most animals cannot digest wood. The termite by itself cannot digest wood either. However, there are microorganisms that live in the gut of the termite. These organisms break down the wood into substances the termite can digest. Both organisms benefit from this partnership. A termite is not born with these small organisms. It must be fed its original supply by older termites.

Many times organisms do not benefit each other. Sometimes organisms compete for food and living space. In this Investigation, you will be studying how some interactions among organisms have survival value.



Worms, insects, and many microorganisms live in the forest soil. Mushrooms and ferns also live in the shade of large trees. Try to identify the organisms in the drawing.

Investigation 15-1
Offense and defense

Provide each group of about five students with a set of dishes. Do not introduce or define the word antibiosis until students have completed their investigations and have operationally defined the concept for themselves.

Radish seeds should germinate in Dish A. Grass seeds should germinate in Dish B. But in Dish C only the grass seeds

Observe the three dishes of seeds. These seeds were planted on the date recorded on the dishes. Discuss your observations with your classmates. What happened in the dish with two kinds of seeds? What inferences or hypotheses can you make to explain what you see?

Do you think you would get the same results if you mixed other kinds of seeds? Are seeds the only living things that interact in this way? In this Investigation, you will try to answer these questions.

Gathering data

Five groups of organisms will be described. These descriptions will help you decide which organisms to use in your investigation. Choose a combination of organisms to study. Try to pick organisms that generally live in the same environment.

There are also some suggested procedures for data-gathering in each section. After you choose the organisms, read the procedures. You can use these procedures or think up your own.

Write a hypothesis about how your chosen organisms interact with others. Design an experiment to test your hypothesis. Discuss your plan of action with your teacher before you start. Write down your procedures and your observations. A series of drawings might help. If you have a camera, you can take pictures to show the changes. However, a camera that can take pictures from as close as 30 centimetres is necessary to show details.

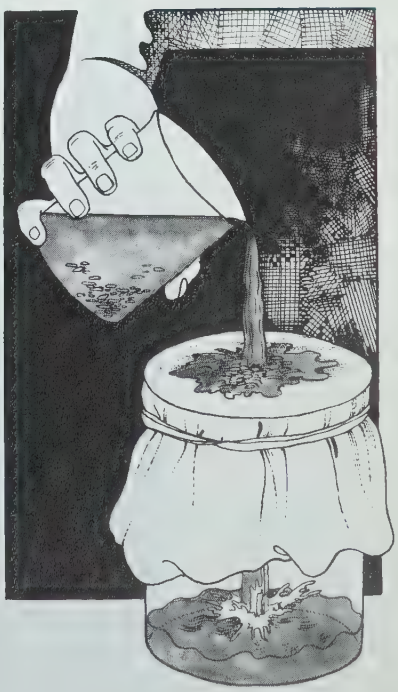
Not all combinations of these organisms exhibit antibiosis. Therefore, the antibiotic effect of one organism (or substances extracted from it) should be tested on several others. For example, the effect of human tears can be tested on all the available species of bacteria. In general, reactions are most likely to be observed between organisms when the organisms are competing for the same resources.

Seeds

You have already seen the results of planting two kinds of seeds together. Will other seeds respond in the same way? What if the seeds are planted in sand or soil instead of on filter paper? What other organisms might interact with a seed in the ground? What part of a seed might affect other seeds?

The radish and Merion bluegrass seeds should be available to students.

Materials
seeds
Petri dishes
filter paper
small beaker or glass
nylon stocking



Suggested procedures All seeds can be tested the same way as the seeds your teacher used. You can also test substances from inside seeds, if the substances dissolve in water. To remove these substances, soak about 30 g of seeds in 150 ml of tap water. The seeds should be soaked for 24 hours. If possible, stir the seeds occasionally during the soaking period. Afterwards, filter the liquid through a clean piece of nylon cut from an old stocking.

You can test several kinds of seeds at the same time in different Petri dishes. Add the filtered liquid from one kind of seed to the dishes.

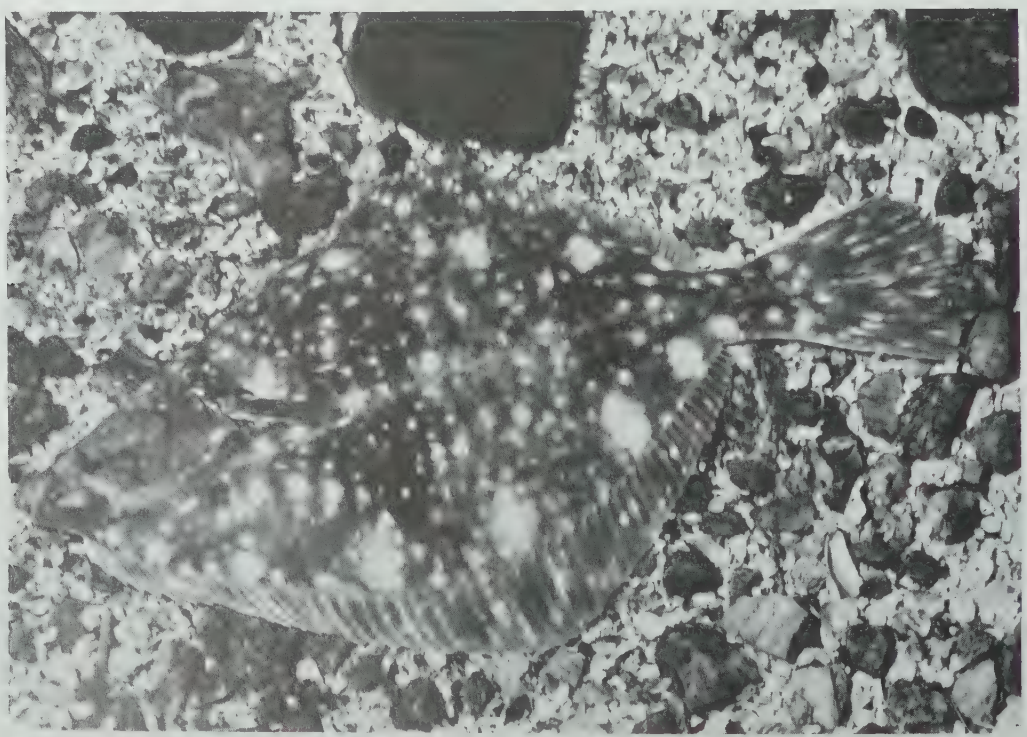


penitent underwing moth



tree toad

flounder



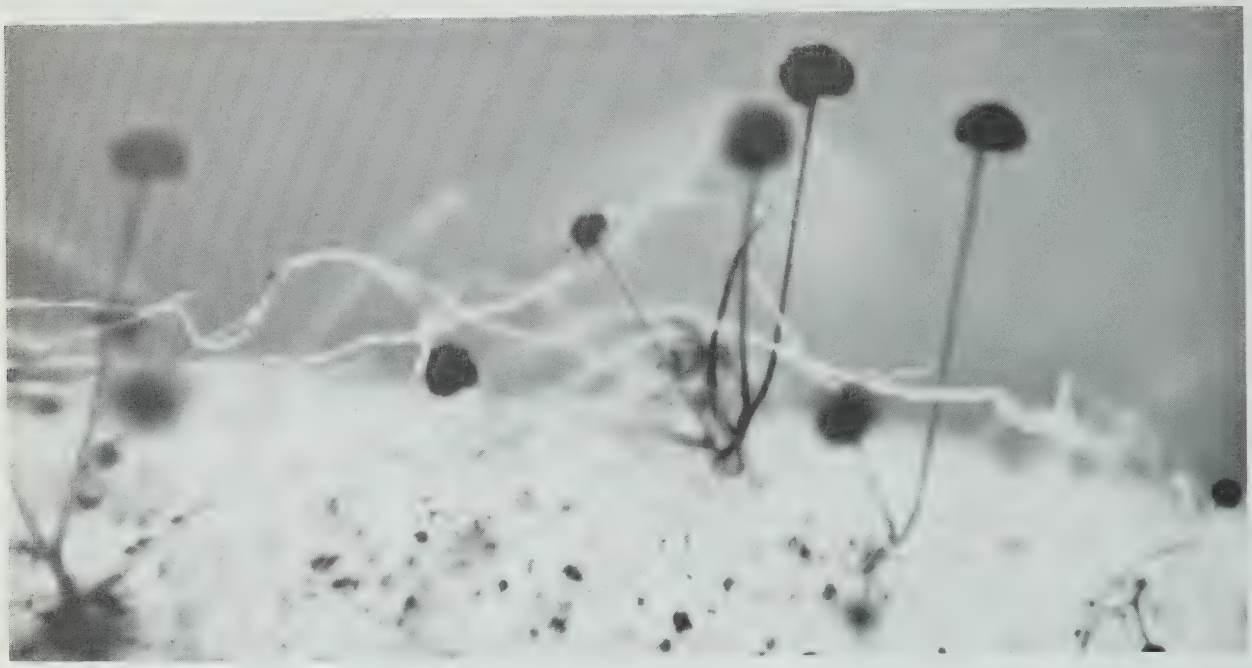


ptarmigan (TAHR muh guhn) in winter

It is hard to spot some organisms because they blend well with their environment. Patterns that help to conceal an organism may protect it from its enemies.

ptarmigan in summer





This photograph of a black bread mold shows the mold enlarged about 40 times.

Molds

Molds cannot make their own food. They often live on dead organisms. They are usually found in dark, moist places. You may have seen them growing on old bread or fruit. When you investigated seed germination, molds may have grown on your seeds. You can also grow them on a special jellylike food called **nutrient agar** (AH gahr).

Do molds and bacteria interact? Are molds affected by seeds, roots, or people? If you decide to work with molds, read the suggested procedures and use the materials in the section on bacteria.

Bacteria

Bacteria are present nearly everywhere. They are in the air, soil, and water. The bacteria used in this Investigation are usually found in the soil. But sometimes they are also found in the food you eat. Bacteria, like molds, grow well on nutrient agar. If you spread a tiny amount of bacteria over a dish of nutrient agar, soon you can see that colonies have grown. Each colony contains millions of bacteria.

Bacterial cultures should not be more than one day old. After 24 hours, contaminant microorganisms become apparent.

Special techniques involving either dilution of the culture or streaking on the agar may be necessary to see individual colonies.

Remember that some bacteria and molds cause disease or infection. None of those used in the class are harmful to people.

But when working with microorganisms, you should not take chances. Everyone in the class must follow these rules. The rules will also help prevent unwanted microorganisms from getting into other experiments.

Students can devise their own methods to suit their own investigations. However, the rules for sterile techniques must be followed to avoid both accidents and contamination.

Students using bacteria can work in one part of the room. This reduces the area of possible contamination by accidents, and allows you to help groups with similar problems (especially learning sterile microbiological techniques) at the same time.

1. Do not eat or drink anything in the classroom.
2. Never put things in your mouth while you work in the laboratory.
3. If you spill a culture of bacteria or mold, call your teacher to help you clean up.
4. Always wash your hands after class.

Materials

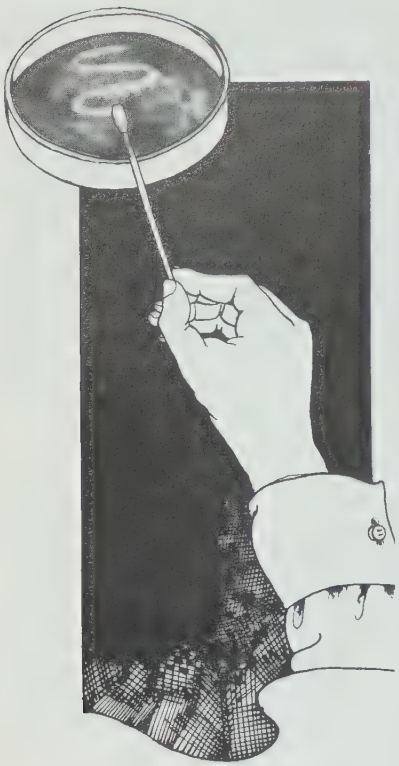
sterile Petri dishes
sterile cotton swabs
test tube of sterile nutrient agar
burner or alcohol lamp
at least 2 kinds of microorganism already growing in tubes of broth

Pressure-cook or oven sterilize the medicine droppers before washing them.

Alcohol lamps will sterilize the mouth of test tubes. But one burner (or hot plate) and a large beaker will be needed to remelt the agar. Make sure the agar is completely melted before it is poured.

Suggested procedures Melt the tube of sterile agar in a water bath. Remove the plug. Flame the open mouth of the tube for two or three seconds to sterilize it as shown. Remove the top from a Petri dish and pour the agar into the dish. Cover the dish





immediately to keep out microorganisms from the air. If the agar does not cover the bottom in a thin, even layer, slowly slide the dish in a "Figure 8" pattern. Be careful not to splash the agar. The agar hardens in about five minutes.

Now take a tube of microorganisms growing in broth. Tap the tube with your fingers to scatter the organisms that may have settled to the bottom. Avoid getting the cotton plug wet. Ask someone to remove and hold the plug for you.

Flame the mouth of the tube. Dip a cotton swab into the liquid. Hold the swab against the inside of the tube to drain excess liquid. Remove the swab. Then reheat the top of the tube and have it replugged. Gently swab the liquid over the surface of the agar as shown. Be careful not to break through the surface. Immediately discard the swab in the container labeled "Used Swabs."

Unplug and sterilize the mouth of a tube that contains another kind of organism. Wet a fresh swab and replug the tube. Gently touch the center of the agar with the swab. Discard the swab in the "Used Swab" container. How should you prepare a second dish to make sure only one variable is responsible for your results?

If you want to test the actions of other microorganisms on each other, ask your teacher for the materials you will need.

Roots and bulbs

Do live roots interact with other organisms in the soil? Do the roots affect the germination of seeds? Will molds or bacteria grow around and on a slice of root, or on a bulb?

Materials

roots or bulbs
seeds
Petri dishes
filter paper
mortar and pestle
piece of nylon stocking
bacteria
molds
agar
cotton swabs
garlic

Suggested procedures You can use pieces of roots you dig up. Or you can cut up roots your teacher provides. Wash the roots well before using them.



Compare the fleshy roots of the iris (top) to the fine roots of the braken fern (bottom).



To see how seeds react to roots, place the seeds around slices of roots on moistened filter paper in a Petri dish. You can also test the effects of root juice. Crush about 30 g of roots in a container with 100 ml of tap water. Shake the mixture well. Then strain the roots out of the juice through a clean piece of old nylon stocking. Add the juice, instead of water, to the dish with the seeds you are testing. Use a separate dish for each kind of seed you are testing.

You can test the effect of roots on bacteria and molds. First, swab dishes of agar with the cultures. (See procedures in the section on bacteria.) Then gently place slices of roots on the agar surface. You can test the interaction between garlic cloves and microorganisms or seeds using the procedures described for roots.

People

People are included as a reminder to students that they interact with other organisms.

You can choose to be a test organism. Some microorganisms, such as the ones that live in your digestive system, help your body function. But unwanted microorganisms can enter your body through your eyes and mouth. How does your body defend itself against unwanted microorganisms? Do you think tears or saliva might affect them?

Materials

piece of fresh onion
several kinds of bacteria
several small sterile test tubes
medicine droppers
incubator or constant temperature box at 37–42°C
small jar
thermometer

Pressure-cook or oven-sterilize the medicine droppers before washing them.

Suggested procedures You can test the effect of tears or saliva on bacteria and molds. For example, you can mix tears with bacteria and observe the results.

Tears contain an antiobiotic enzyme called lysozyme, capable of breaking open bacterial cells. When the cells break, the solution becomes clear or thick, or both. A high concentration of lysozyme will usually cause a dramatic reaction within 30 minutes.

Collect tears from a classmate. Have him hold a slice of onion near his nose. Then you can catch the tears in the sterile test tubes. Collect seven or eight teardrops in a test tube for each kind of bacteria you want to test. Label each test tube with the name of the kind of bacteria you use. Using a medicine dropper, add 20 drops of bacteria to each tube. Plug the tubes. Place the dropper in the container labeled "Used Droppers." Write down a description of the liquid in the tubes. Gently shake the tubes



to mix the bacteria and tears together. How should this experiment be controlled?

There should be a tube containing tears but no bacteria.

Mix hot and cold water in a small jar to get a temperature between 37–42°C. Put your tubes in the jar of water. Keep the jar at 37-42°C by adding hot water when necessary. After 15–20 minutes, observe the liquid in each tube. Does it look less cloudy? Is it thicker? If you do not see any change, put the tubes in the incubator at 37–42°C overnight.

If you want to work with saliva, use procedures similar to those described for tears. Rinse your mouth with water before collecting the saliva. What is the reason for rinsing your mouth?

Rinsing the mouth will help remove any bacteria or food that has accumulated.

Analyzing data

Discuss the results of your own investigation and the ones your classmates did. Review the questions and hypotheses that led to your investigation. Did you find any answers to your questions? Did the data support your hypotheses?

What kinds of interaction were noted? How might the interactions that you observed benefit the organisms? Does their behavior help them survive? Many of the interactions your class observed are called **antibiosis** (AN ty by OH suhs). In these interactions, one organism produces a substance that harms another organism. Can you think of any other examples of antibiosis?

After students have analyzed and exchanged their findings, help the class synthesize its data. If necessary, help students distinguish experiments that demonstrated antibiosis from those that did not. Students should come to view antibiosis as an interaction in which many kinds of organisms participate, an interaction that helps some compete and survive. See the Background in the Teacher's Manual for other examples of antibiosis.

How does the appearance or the behavior of these animals help to protect them from predators?



opossum

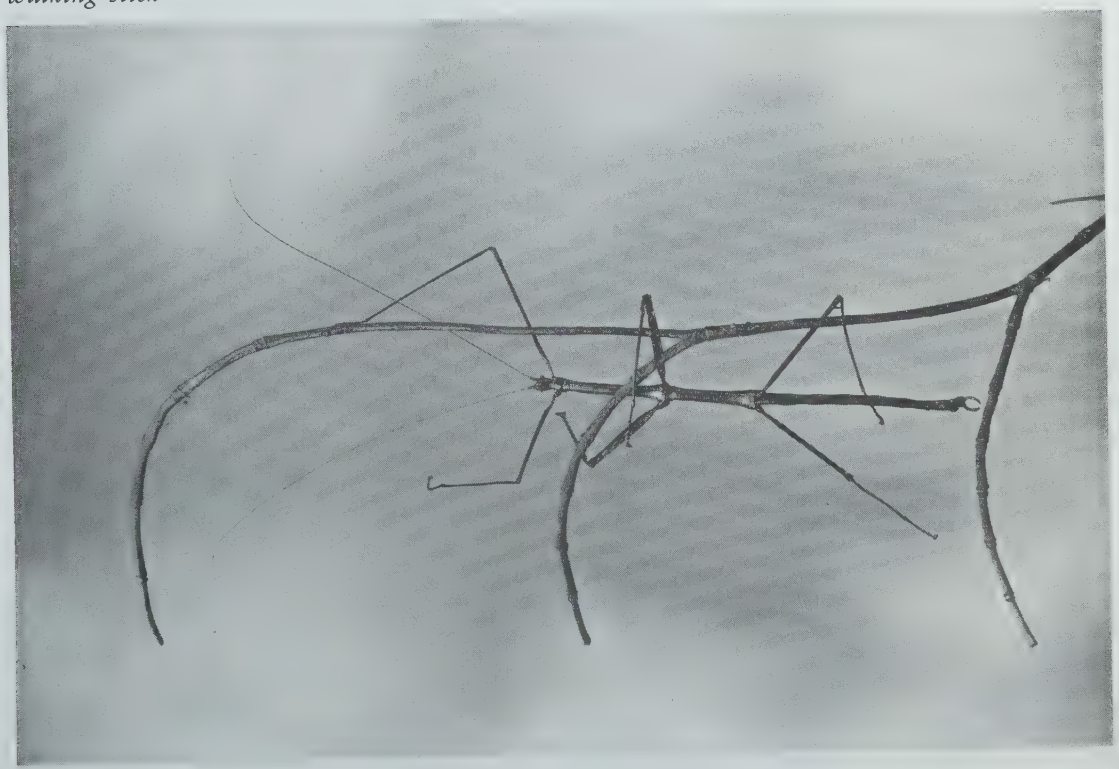
Key West anole





true katydid

walking stick



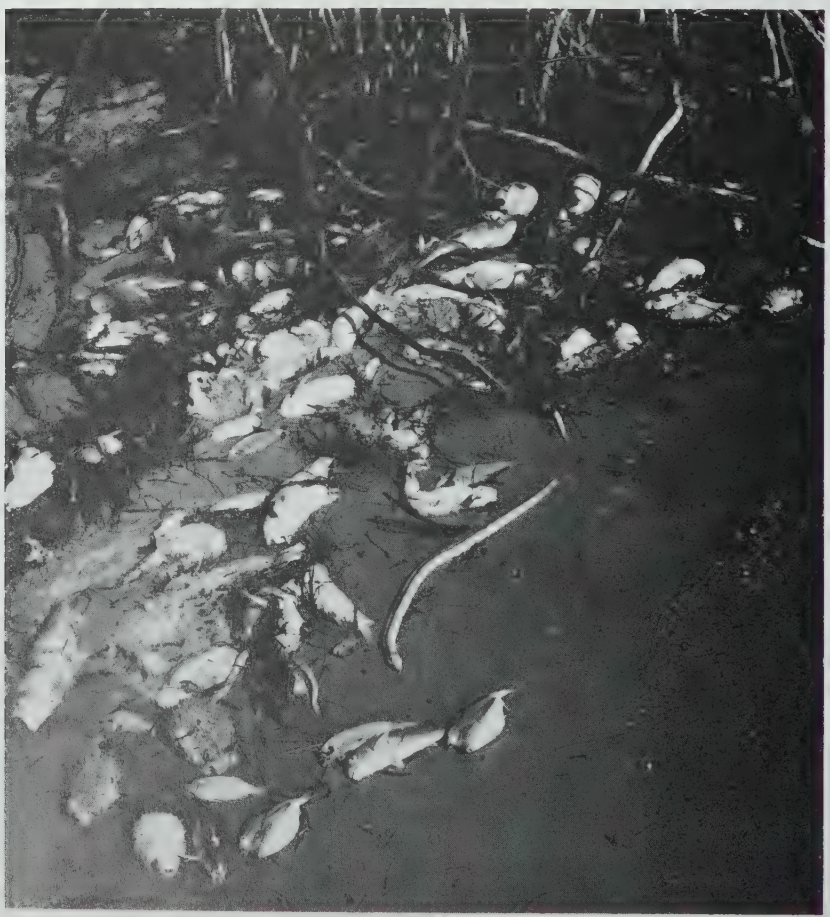
Extend Your View 15-1
When the tide turns red

For additional information on the "red tide," refer to *The Frail Ocean* by Wesley Marx.

Can you design an experiment to explain an interaction between organisms? Along the Florida coast of the Gulf of Mexico, the sea sometimes becomes red. To the people who live along this coast this "red tide" has a special meaning. When the red color appears, they expect thousands of fish to die soon and wash onto the beaches.

Scientists who examine the water discover that it is alive with red microorganisms. Scientists have nicknamed the organisms "Jim Brevis," after its scientific name, *Gymnodinium brevis* (jihm noh DIHN ee uhm BREHV ihs). Did Jim Brevis kill the fish? If so, were the deaths caused by antibiosis?

Suppose you could conduct experiments to test the effects of Jim Brevis on healthy fish. Design an experiment you would use to find out if fish are killed by a substance from Jim Brevis. What data would show that such a substance was the cause of death?





Extend Your View 15-2
Life and death in the desert

Can you infer how substances produced by organisms are related to their survival? Death Valley, a desert in the United States, is a very harsh environment for plants and animals. Yet, a variety of both kinds of organism live there. Among these is the evergreen creosote (KREE uh soht) bush. These bushes are spread evenly over the desert. The young seedlings that sprout near the creosote bushes soon die. This happens even when there is enough water to support the growth of these young plants.

Write a hypothesis that might explain why the young plants die, resulting in the creosotes' even spacing. Give reasons for making your hypothesis. What advantage does the adult creosote bush gain when the young plants die?



16

Planet management

After you complete this Investigation, you will be able to

1. select some ideal conditions or goals for the management of a planet.
2. use goals to choose between two projects for solving the same problem.

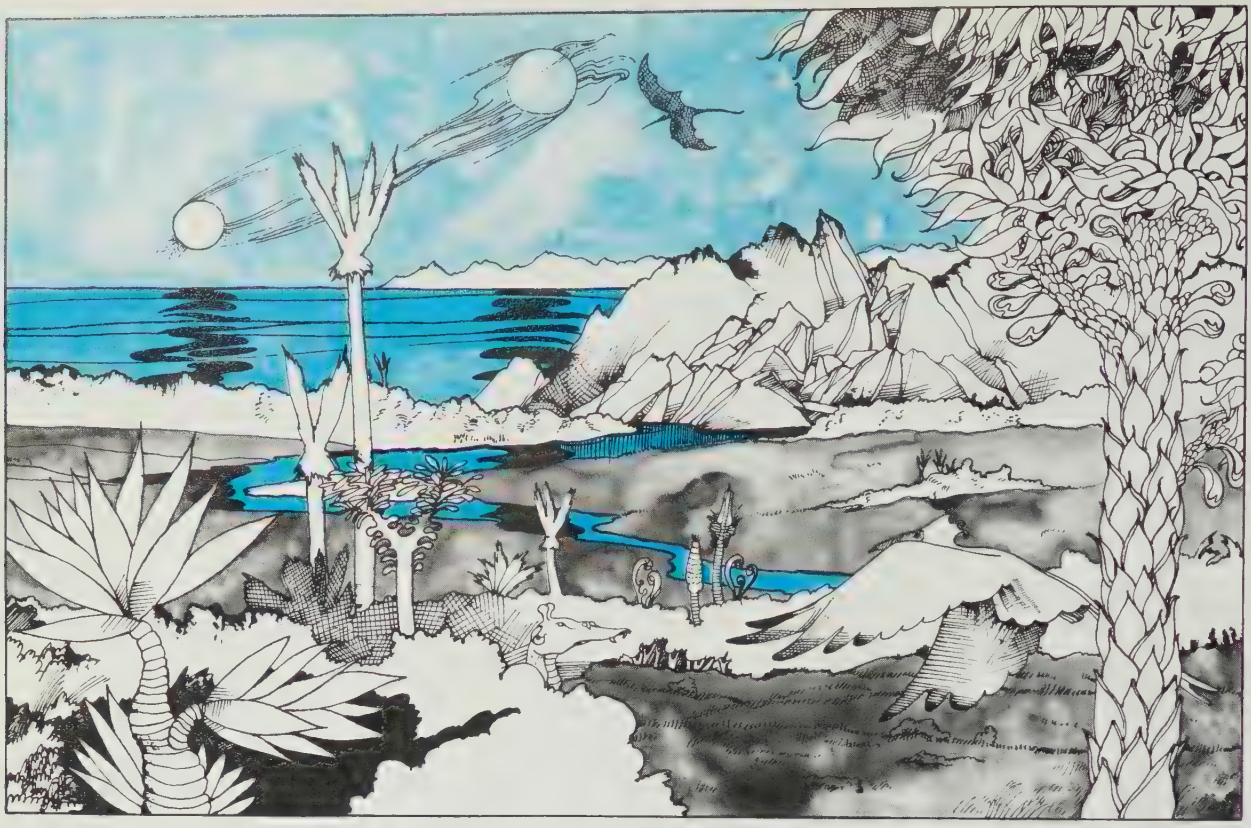
How many people can live on Earth? Is there a limit? Almost 200 years ago, Thomas Malthus predicted that a limit would soon be reached. Population would increase until food ran out. Then many people would starve to death. Malthus did not consider that improvements in farming would greatly increase food production. Some people say his prediction will still come true—only later than he thought. Other people say that food production is not that important. For example, India has a food shortage. Many people die of famine. Others are undernourished. Yet India has one of the fastest-growing populations on Earth.

The variables controlling the growth of human populations are not easily studied. One reason is that these variables cannot be controlled in a laboratory. However, in this Investigation, you will experiment with a population of beings on the imaginary Planet Clarion. You will probably find the Investigation more interesting if you use your imagination. The more realistic Clarion becomes, the more you will learn.

Have you ever heard someone say, "If I could run this world, it would not be in such a mess."? Now is your chance to run a world.

Here are several ways to promote involvement:

1. Challenge students to draw sketches of what Clarionites might look like.
2. Maintain a bulletin board display of "newspaper headlines" or articles from Clarion.
3. Have students describe a day in the life of a Clarionman or Clarionwoman.



Perhaps this is what Clarion looked like before the colonists arrived. What do you think Clarion looked like?

Investigation 16-1

How can Clarion be improved?

Imagine that you are living in the year 2000 A.D. You have a job with Universal Planet Management Associates. You and your team will manage the Planet Clarion for the next 50 years.

As "Managers of Clarion," your team has to decide how to spend the money available to take care of Clarion's needs. You will set up a new budget every five years. At the end of each five-year period, you will find out how the planet has changed. You will keep track of population change, income, food supply, and the condition of the environment. You can use this data to decide on your next five-year budget.

The standard of living on Clarion is measured by the four indexes, not just income as is sometimes done on Earth.

The Planet Clarion is like Earth in size and climate. But the land area is smaller than Earth's. All the land is on one continent. The rest of the planet is a blue-green ocean that is much less salty than Earth's. Some of the land is flat and has a mild climate that is good for farming. There are some deserts that are fiery hot during the day and cold at night. There are other regions of bare rock that separate the fertile areas.

The organisms on the planet are similar to those on Earth. But there are no native animals like humans. The Council of Civilized Planets transported 100 000 colonists to Clarion from the Planet Rasmuss. These colonists are similar to humans. But they are smaller and have shorter life-spans.

There seems to be only one major threat to life on Clarion—the disease Holobinkitis. It attacks both plants and animals, including Clarionites. No one knows the cause of the disease or a cure for it. It is almost always fatal.

Clarion has one large and unusual mineral deposit. The mineral is Walterite ore. Some scientists say that the metal obtained from the ore is superior to iron or steel. Walterite is usually found under a thick layer of hard rock. It is difficult to mine.

The Clarionites do not yet produce all the things they need and want. Food sometimes becomes scarce, and it is very expensive to import food from other planets. One of the big problems is the damage to crops caused by insects.

Most of the Clarionites say they will stay in spite of the hardships. They believe Clarion has a bright future. The Clarionites usually give three reasons for leaving their home planet of Rasmuss:

1. It was getting too crowded there.
2. There was a promise of better life on Clarion.
3. Clarion is a beautiful place to live.

Materials

The Planet Management Game, including:
- Planetary Status Ledger
- Project Guide and Cards

4 marking pencils of different colors
4 pieces of graph paper
coin

Gathering data

One game lasts ten rounds. Each round represents five years. In each round you have a limited amount of money to spend on different projects. The object of the game is to have the best possible conditions on Clarion at the end of 50 years.

Read the instructions before playing the game. Then play two rounds to learn how to play and how the different projects (*if-variables*) affect the indexes (*then-variables*). After these two rounds, your team or class should discuss what "ideal conditions" you want to achieve. Then finish the game and compare your results with the results of others in your class.

The planetary status ledger

Before starting, you should understand the Planetary Status Ledger. It is like a scorecard for the game. There is a place to record how you spend your money (Project Record) and a place to record changes in the four indexes.

The **population index** begins at 100 units. Each unit stands for 1000 Clarionites. At the beginning of the game there are 100 000 Clarionites. If the population index changes to 104, this means the population has increased by 4000. There would now be 104 000 Clarionites.

The **food index** begins at 100 units. Each unit stands for the minimum amount of food for a well-balanced diet for 1000 Clarionites. If the food index were less than 100, some people would be undernourished or maybe starving. If there were more food units than Clarionites, the extra food could be stored for future use.

The **income index** begins at 100 bux. This index shows the money earned by all the Clarionites in one round. Suppose the income index goes up to 120, while the population index stays at 100. This means the average income has risen. Suppose the income index stays at 100, and the population index goes up to 120. The situation would be reversed. More Clarionites would depend on the same income, and the average income would fall.

If average income rises, the total amount of money that could be spent has increased. Actually, how the money is distributed would depend on the type of economic system on Clarion.

The **environment index** measures the quality of Clarion's environment. The index was at 100 when the first Clarionites arrived. The Clarionites have changed the planet and the index has dropped 10 points. It is now at 90.

The rules

To involve everyone in the action, suggest that the players on a team take turns making the final selection of projects (after a team discussion).

1. Read the Project Guide and select the projects you would like for Clarion. Pick only one project from each color group. You may spend 2, 4, or 6 bux on any project. You cannot spend more than 10 bux in any round. You may decide to spend less.

   Example:

   Project B—2 bux
   Project H—2 bux
   Project K—6 bux
   No project in the yellow group
   No project in the green group

2. Record your selections and the amount spent on each in your notebook. Place the Planetary Status Ledger over a blank page. Fill in the letter of the project and the amount spent on each project in the cutout window.

Example:

PROJECT RECORD						
Round	Amount Spent					
	red	blue	orange	yellow	green	Total
1	*B-2*	*H-2*	*K-6*	*M-0*	*R-0*	*10*

3. Select the Project Cards that match the projects and the amounts spent on each. If you do not spend anything in one color group, use a "no project" card for that group.
4. Place the Project Cards together. One hole (and only one hole) should open through all of them.
5. In the booklet find the data-sheets labeled Rounds 1 and 2, population change. There are four sheets in the set, numbered 1–4.
6. Flip a coin twice to decide which data-sheet to use.

Each person can manipulate the Project Cards on successive rounds.

First flip	*Second flip*	*Use data-sheet*
heads	*heads*	*1*
heads	*tails*	*2*
tails	*heads*	*3*
tails	*tails*	*4*

The coin-flipping simulates randomness for selection of data-sheets. Each data-sheet is slightly different. This approximates the lack of precise control and the effect of "luck" that exist in real life.

7. Place your set of Project Cards on the data-sheet and read the results through the open hole.

   Example: You flipped heads first and tails second. You place the cards on Data-sheet 2, and a "4" shows through. Record the change in population, 4, on the Planetary Status Ledger.

8. Add the change to the population index and write the results on the new index line. If the change is negative, subtract.

   Example: Starting with 100 and adding 4, gives 104 as the new index.

9. Repeat Steps 6 and 7 for income change, food change, and environment change. Use only the data-sheets labeled Rounds 1 and 2. When you have recorded the changes for all four indexes, you have finished Round 1.
10. To play Round 2, pick a set of projects and proceed as you did in Round 1. You may use the same or different projects.
11. After two rounds, discuss with your team how the different projects affected the indexes. You should set some goals at this time. What conditions do you want by Round 10?
12. As you play Rounds 3 through 10, be sure to use the right data-sheets. Keep graphs of changes for each index. This will help you to see the results of your projects.

During this discussion, you might ask students to predict the effects of different projects on each index.

PROJECT GUIDE

RED CARDS

A No project in this color group
B Clear more land and prepare it for raising crops
C Import chemical fertilizers and pesticides
D Buy machinery to plant, cultivate, and harvest crops

BLUE CARDS

E No project in this color group
F Conduct research to develop new varieties of corn, wheat, and rice with higher yields
G Conduct research to identify the cause and cure of Holobinkitis
H Conduct research to find better ways to mine and use Walterite

ORANGE CARDS

I No project in this color group
J Build more Walterite mines and purification plants
K Build more highways and railroads to connect towns
L Construct new electric power plants

YELLOW CARDS

M No project in this color group
N Build more schools for all age groups and for general, professional, and technical education
P Pay people to go to graduate schools of civil engineering, biochemistry, medicine, and agriculture
Q Finance the "Einstein Plan"
This would a) send a few of the most capable individuals to Earth for advanced study, and b) connect more Clarion homes to the educational television network.

GREEN CARDS

R No project in this color group
S Construct more and improved sewage-treatment plants for city and factory wastes
T Finance the Wright Plan
This would a) buy areas of land around lakes and oceans to be used for recreation, and b) build high-rise apartment buildings in the center of cities. The buildings would be surrounded by large parks.
U Equip more chimneys of homes, industries, and other buildings with anti-smoke equipment



Analyzing data

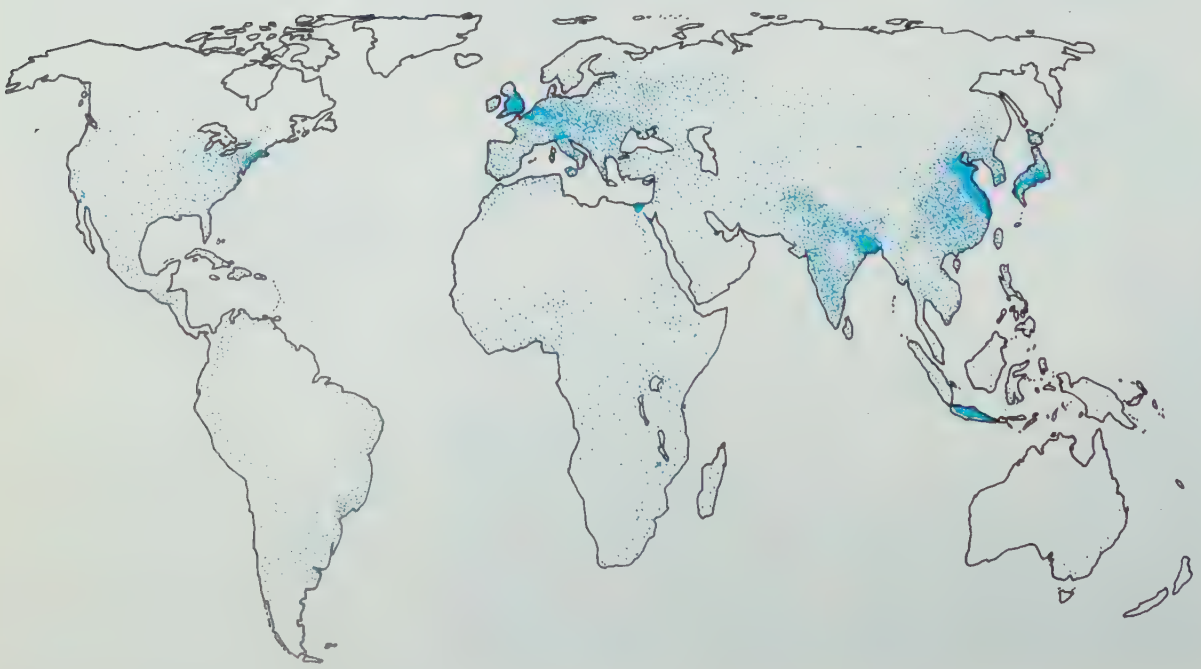
Discuss with other Planet-Management teams what the ideal conditions on Clarion should be after 50 years. The winner of the game will be the person or team who came closest to the ideal conditions. Here are some things you can think about in choosing a winner:

1. Were the same results obtained by spending less money?
2. Which set of final index values would you prefer to live with?
3. Is there enough food and income for the population?
4. If the patterns you have noted continued for another 50 years, would you want to live on Clarion?

You might ask the students how investing in Project G might affect the population index. Finding a cure for Holobinkitis would increase the average life-span of Clarionites and the population problem.

You might want to play the game again, now that everyone has agreed on the ideal conditions for the Planet Clarion. How do conditions on Clarion compare to conditions on Earth? Would population control improve conditions on Clarion? on Earth? What indexes (*then-variables*) should be included in an Earth-Management Game? Why?

This map shows which areas in the world have the most population. The areas that are solid blue have the greatest population density.



Extend Your View 16-1
The environment index

Can you select some ideal conditions for the management of a planet? In *The Planet Management Game,* the exact meaning of the environment index was not defined. What would it mean if a team set these goals for the environment index?

1. To make the index 100 by the end of the game.
2. To keep the index above 70 at all times.
3. To increase the index above 100.

Extend Your View 16-2
Transportation problems on Clarion

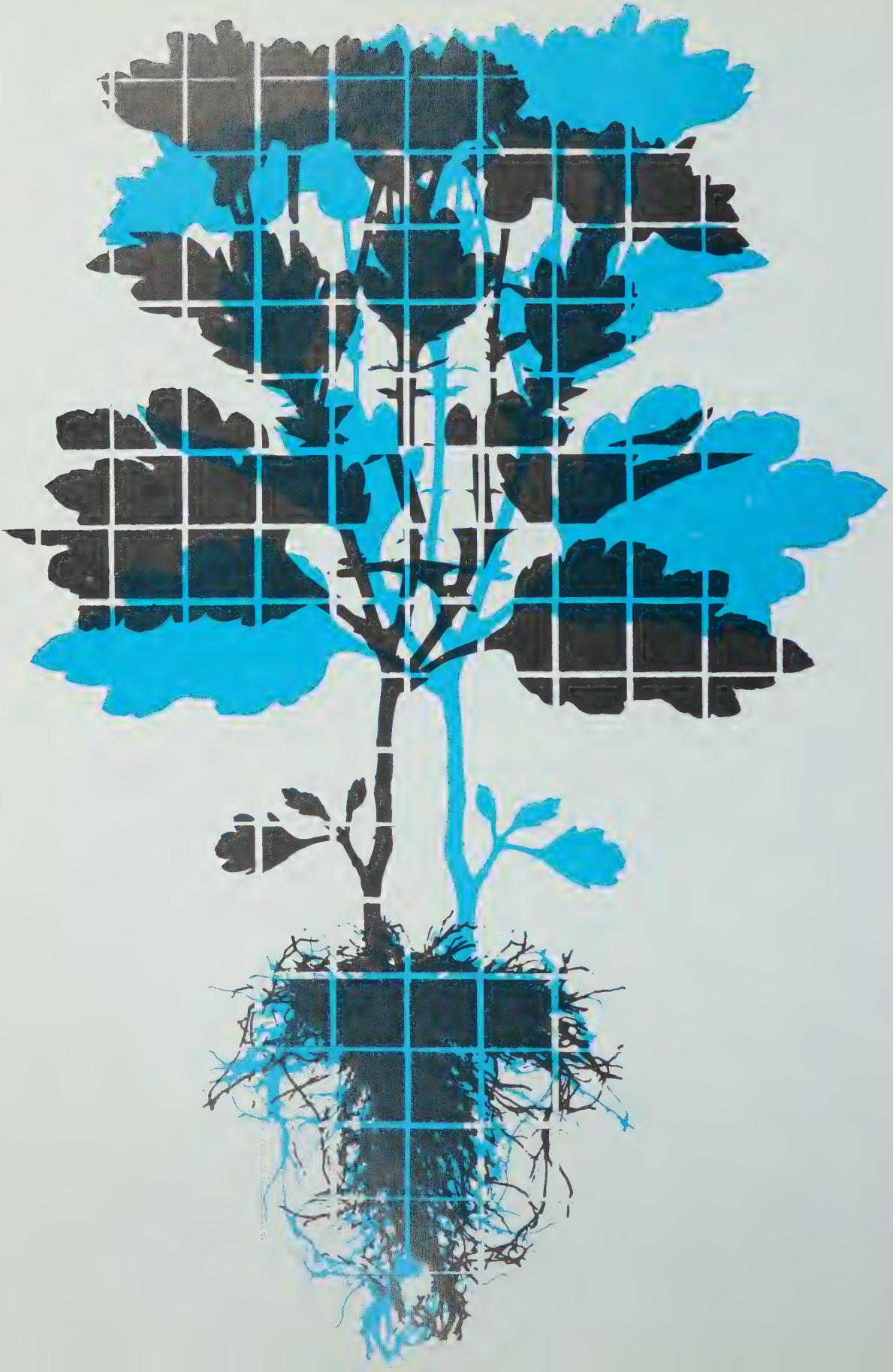
Can you use goals to choose between two projects for solving the same problem? Suppose you are the mayor of Virena City on Clarion. Most of the Clarionites that work in your city live far away in the country. About 80 percent of them drive to work in their private cars. More Clarionites would use public transportation if it were more convenient, cheaper, and faster. It is now less expensive than driving a car, but not as convenient.

Until now, all the money supplied by Project K has been used to develop better roads into the city. As a result, more and more Clarionites found it easier to drive their cars. Now even these new roads cannot handle the traffic.

A new round has begun and Virena City has been given one buc to solve the problem. Choose one of the two projects and explain why you made that choice.

Project 1: The one buc would be used to expand the present program of road building. New roads would be built into the city to handle more cars. Using this project each round would build enough roads to handle the traffic. Cars would also be fitted with devices to reduce noise and air pollution.

Project 2: The one buc would be used to build a rail system into the city. The rail system would make public transportation more convenient, cheaper, and faster. Less fuel would be needed since trains use less fuel per passenger than cars. There would also be less pollution. This system would take one round to build; so the traffic problem would temporarily get worse as the number of cars increased and road building did not. Once the system is working it will handle the predicted population for two rounds before the project must be used again.



Unit FOUR

People affect the environment

17

People cause change

After you complete these Investigations, you will be able to

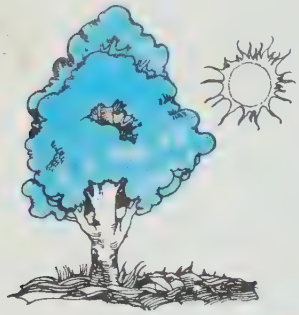
1. infer some of the consequences of changes people make in their environments.
2. identify the kind of data needed to check these inferences.

People do many things to change the environment. They build fires to keep warm and to cook food. They build homes and factories. They build roads and dam rivers. They farm the land and dig minerals from underground.

Sometimes people make more changes than they realize. For example, building a house on an unused lot may seem like a simple change. But there are many questions to consider. How will the plant life change? Will flowers and grass replace weeds? Are food sources and shelters for animals changed? Will the fuel used to heat the house pollute the air? Will the sewage and detergents from the household pollute the water? Will the town have to provide more schools and hospitals? What are the total changes made in the environment?

In this unit, you will look at how people affect their environment. These Investigations should help you focus on the kinds of data you will need.

Investigation 17-1
The effect of using energy

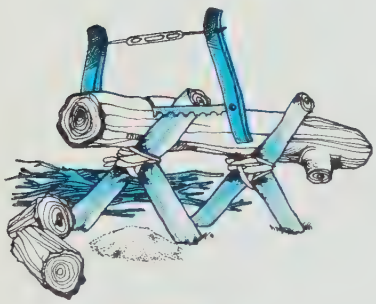


When an energy source is used, it changes the environment. What energy sources are being used in your home, school, or community? Do plants have an energy source? Energy sources change as they are being used. This drawing shows some changes that happen to one energy source—wood. Which steps affect the environment?

Gathering data

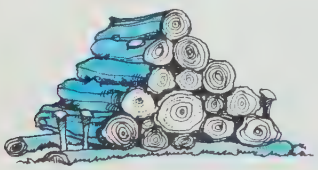


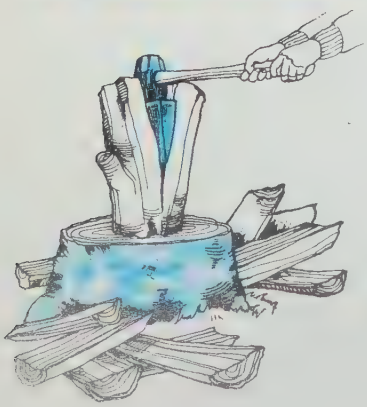
As a class, identify an energy source that is used in your community. Make a diagram similar to the one for wood. If possible, trace the source from its origin. Identify the steps that you think affect the environment. Then divide into small groups. Have each group investigate how one step affects the environment. You can get information by doing experiments or from newspapers, people in the community (interviews), magazines, and books.



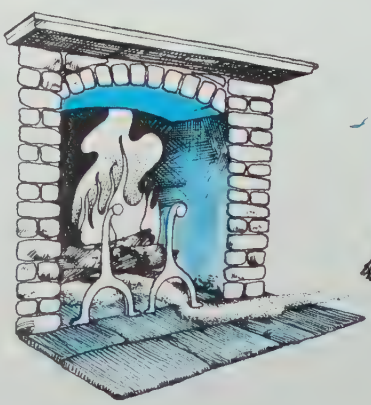
Analyzing data

1. Could your diagram of the energy source be more accurate? Are there important steps missing?
2. Which steps changed the environment? Which changes are "good"? Which changes are "bad"?
3. Why does your community use this energy source? Do all people gain something by its use? Do some people lose something? How many people get to choose their energy source?











4. What questions do you still have about how your energy source affects the environment? What additional data would you need to answer them? What kinds of data would be most helpful?

If students are familiar with the technique, they could also use flow charts to analyze the steps involved in the use of an energy source.

Investigation 17-2
Changing the earth's surface

Mining is a way people get resources from the earth's crust. Coal, sand, gravel, gold, copper, phosphorus, and clay can all be mined. Some of these resources are found deep in the earth. Shafts must be built. People and machines must work hundreds of metres below the surface of the earth to recover these resources.

Other resources are found near the surface of the earth. These are mined in quarries or pits. Another kind of surface mining is called **strip mining** because large areas of land are "stripped" to get at a buried resource.

Coal is a valuable resource. It is an energy source for many electric power plants. Companies strip-mine for coal that is found in veins or beds near the surface. Some of these beds extend for hundreds of kilometres. Some coal comes from deep mines, but every year more coal comes from strip mines because strip mining is a less expensive method.

Gathering data

The photographs in this Investigation tell about strip mining for coal. Make a list of the changes you observe and the changes you infer. Think of changes in the immediate area. Also think of changes that affect more distant regions.

The photographs on page 209 show a region in the foothills of the Appalachians. There are streams, rivers, and rolling hills. Much of the land is used for growing crops, for grazing cattle and sheep, and for raising pigs and dairy cows. The towns are generally small. Where farmers are not using the land, more shrubs and trees can grow. There are some large forests of oak and hickory trees. Deer, foxes, skunks, squirrels, chipmunks, owls, hawks, and other birds live in these forests. These animals like the woods and shrubby areas because of the food and shelter these areas provide. In addition to their own domesticated animals, farmers share their land with rabbits, mice, snakes, and birds.

This is one of the largest shovels used for strip mining. It is twelve stories high and its bucket can hold 200 tonnes of earth. (This amount of earth could fill about three city buses.) This shovel is sitting on a coal bed. It does not dig the coal, but is used to remove the soil and rocks above the coal. Smaller shovels and bulldozers move in behind the large shovel and load the coal into trucks. The rock layers on top of the coal bed are often difficult to remove. They are broken up first with dynamite to make it easier to dig. The shovel picks up rocks from the cliffs and deposits them in a pile. This pile of broken rocks and soil is called a **spoil bank.**

After mining, companies reclaim or restore the land they have used. How much reclamation they do depends on local laws, and how much time and money the companies want to spend.





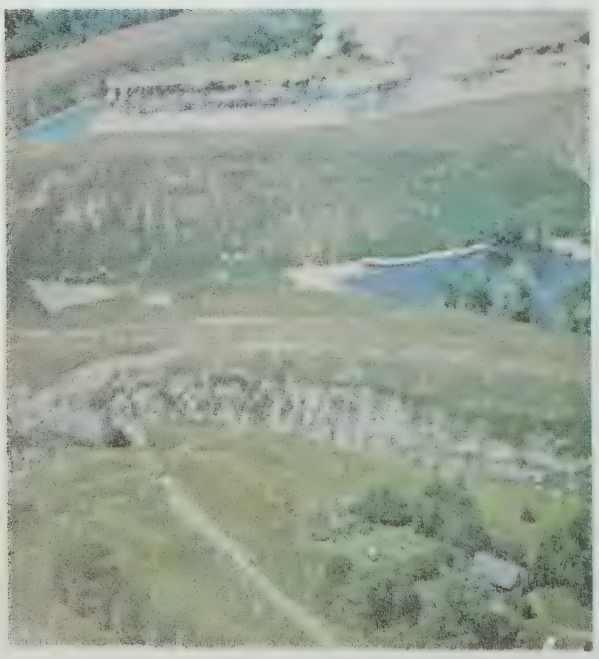
These are two typical landscapes in the foothills of the Appalachians.





This aerial view shows the extent of a strip-mining operation.

This is one attempt to reclaim land that has been strip-mined.



This strip-mined land has been planted with fir trees. Notice the rocky soil and the small gulleys.



Spoil banks are unstable and erode easily. Erosion results in gulleys. Erosion also clogs nearby streams and lakes with sediment.

When mined land is reclaimed, the spoil banks should first be leveled. The land is covered with vegetation that will help stop erosion. It is important to get plants growing right away to help stop erosion and start building new soil. But very few plants will grow on rocky spoil banks. Some plants that are good for reclamation are crown vetch, alfalfa, clover (which can be used to feed cattle), and black locust trees. Often companies must seed and reseed many times before any plants will grow.

Analyzing data

1. What changes did you observe or infer from the photographs?
2. What problems could occur because of each change? what benefits?
3. What data do you need to check your inferences?

The answers to these questions should key in on changes, reasons for changes, and ways to verify inferences. You may want to discuss the "good" and "bad" implications of strip mining. Students will have to make similar value judgments in later Investigations.

Extend Your View 17-1
Building a dam

Have you learned to infer some of the consequences of changes people make in their environments? Can you identify the kind of data you need to check your inferences? Dams are built for various reasons. If a dam has been proposed for your area, gather data on the proposed site. Consider how the environment would change if the dam were built. If there is already a dam in your area, some older residents may have information about the river before the dam was there. If there is no local dam to study, choose a dam that you can read about in the library. The United States Corps of Engineers is a good source for information on dams.

If there is no dam in your area, the class may want to study a levee, a weir, or any structure that interrupts the flow of water.

1. What changes can you infer have occurred because of the existing dam or would occur if the proposed dam were built?
2. Infer why the dam was built or is being proposed. How could you check your inferences?



18

What changes your environment?

After you complete these Investigations, you will be able to

1. identify changes in your environment.
2. identify examples of energy flow and pollution in your environment.
3. explain how the interruption of one form of energy flow affects the environment.

Does brushing your teeth or taking a bath make you think of pollution? The toothpaste and soap that you use go down the drain. Fertilizers and weed killers are used on lawns and gardens. These sink down through the soil into the underground water supply. This water eventually drains into streams and lakes. In some communities, human wastes end up in cesspools and septic tanks. But in many communities, these wastes end up in sewers. The sewers empty into a lake, river, or the ocean. Do you think these substances affect the water and the organisms that live in it?

The earth's shallow crust and the layer of air that surrounds the earth contain all the air, soil, and water that we will ever have. This is the environment upon which we depend. Since no materials are added to this environment, everything must be **recycled,** or used again and again. Many of the products that people produce cannot be recycled. This causes one kind of pollution—the piling up of solid wastes.

Sometimes people blame large industries for all the pollution. Many people do not think that they personally affect their environment. Do you think this is true? In these Investigations, you will look at how your immediate environment changes.

Investigation 18-1
Finding changes in your environment

This is a rather open-ended Investigation. Encourage imagination in identifying examples of change. A short class discussion may help demonstrate the wealth of changes in their environment.

How do you know that a change has occurred? If you see a car accident, you can observe a change happening. But sometimes you have to infer that a change has taken place. If you see a wrecked car, you might infer that an accident has occurred.

In this Investigation, you will look for changes in your environment. Your class will decide whether to investigate your entire community or merely the school grounds.

Gathering data

This Investigation could be done in class or as a homework assignment. In either case, students should be allowed to collect data outside the school. A field trip around the community can provide useful data.

Examine the environment you are studying. What changes can you infer have taken place? What is your evidence for each inference? Find at least five changes that you would classify as "useful." Find at least five that you would classify as "harmful." Are the harmful changes examples of pollution?

Analyzing data

A guest speaker may be able to add substantial information on some aspect of environmental change. Films or field trips are also effective. You may want to relate what students in other classes are doing. Often, an ambitious or imaginative project by a few students will precipitate even more enthusiasm in other students.

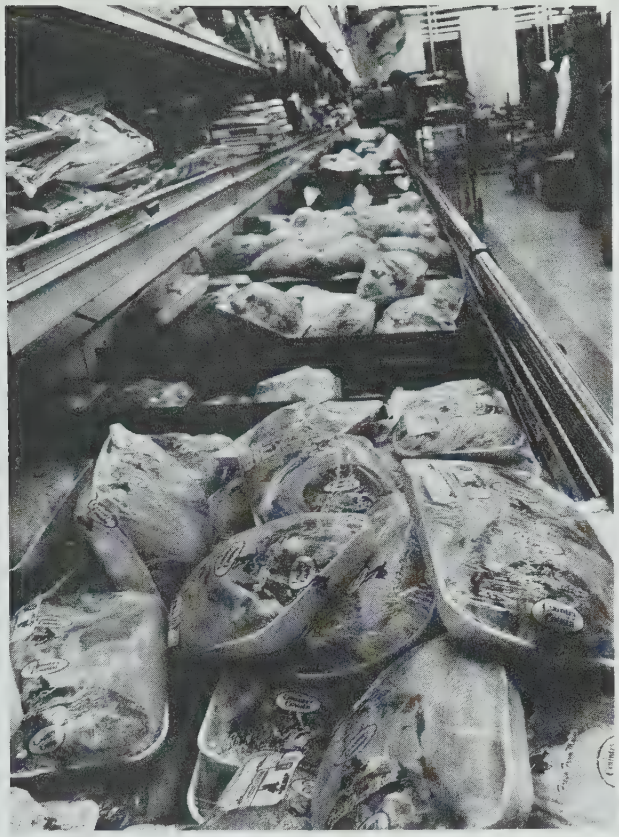
Discuss the changes you find with your classmates. Which of the changes are related to energy use? Which were caused by people? Think of other ways to classify the changes.

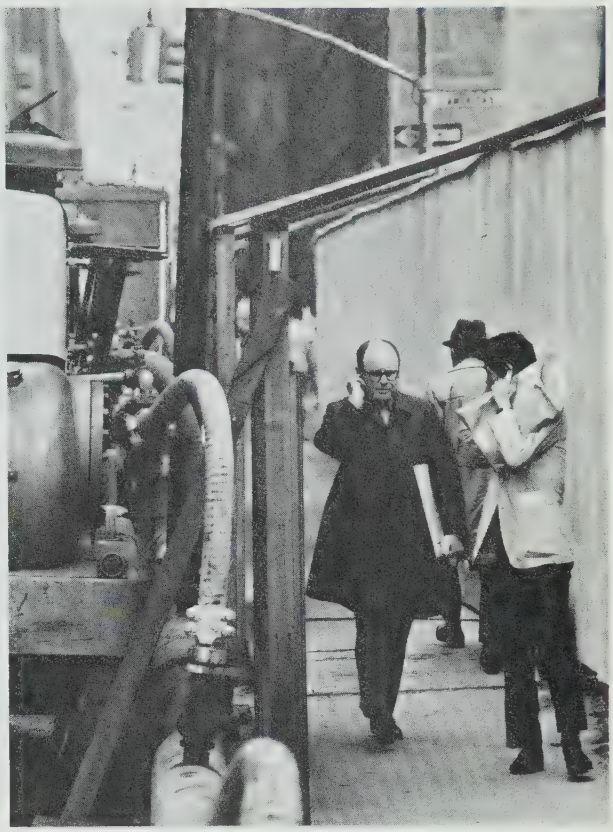
1. What kinds of change improve the environment?
2. What kinds of change are more often examples of pollution? What is pollution? Can your class agree on a definition?
3. What kinds of change make people's lives easier? Does an "easy life" necessarily mean more pollution?

Investigation 18-2
How does your home affect the environment?

A short discussion might help make students aware of the vast number of input and output items. Consider natural gas, electricity, light, air, heat, noise, moisture as well as people and food.

Your home is part of your environment. To find out how your home changes the rest of your environment, make a list of everything that comes into your home (input) and a list of







Do you see any examples of pollution in the situations in these photographs?

everything that goes out of your home (output). For example, cold water enters your home, is heated, and leaves as hot, soapy water.

Gathering data

Make input and output lists for your home. Be as thorough as you can. Be quantitative when possible. You could get information on quantities of electricity, water, and fuel either from bills or from meter readings. You could also measure the mass of items bought and items discarded.

Analyzing data

Identify the items on your input and output lists that involve energy use. Put an **E** by each of these items. Identify the items on your input and output lists that you think are examples of pollution. Put a **P** by each of these items. Trace each item on your input list to one or more items on your output list.

1. Look at the list of **E**-items. Trace the energy from the input list to the output list. This shows energy flow. Suggest ways of saving energy. Would these suggestions change the way you live?
2. Look at the **P**-items on both your input and output lists. On which list are there more **P**-items? Suggest ways of reducing pollution.
3. Are there any output items that could be used as input items? This would be an example of recycling.
4. How does your home affect your total environment?

Investigation 18-3
What happens when energy flow is interrupted?

In Investigation 18-2, you identified some examples of energy flow in your home. These may have involved gasoline, electricity, heat, light, and motion. There are similar examples of energy flow in the rest of your environment. You may be able to find more examples as you gather and analyze your data.

In this Investigation, you will study energy flow by investigating energy interruptions. What situations have you experienced, read about, or seen on television where energy flow has

been interrupted? When was the last time your home was without electricity? Has a car you were in ever run out of gasoline? Would a heavy snowfall or a washed-out bridge lead to an energy interruption?

Gathering data

As a class, think of some examples of energy interruptions. Then choose one or more situations to investigate. The class should make a hypothesis about the effects of each interruption. Gather data to support or reject the hypothesis from newspapers, magazines, television, or interviews. You may want to take photographs or use a tape recorder. Try to gather as much quantitative data as you can.

If the situation you have selected is complex, the gathering of data can be divided among several groups. For example, if your class is investigating a taxi strike, some classmates can gather data about the energy flow before the strike. Others can investigate the effects the strike had on other forms of transportation such as buses or private cars. And others can investigate what happened when the strike ended.

Allow the students to try to organize themselves so they can collect data effectively. If this does not work, you may have to group the students. As you direct their activities, use fewer explicit directions and more thought-provoking questions. Have a tape recorder, camera, or other pieces of equipment handy for use by the students.

Analyzing data

Each group will present its data and any conclusions it has reached to the rest of the class. The class will then analyze the data.

1. What was the condition of energy flow before it was interrupted? What form or forms of energy were stopped from flowing in the situation you studied? What other forms of energy were affected by the interruption?
2. How long was the interruption? Did the environment return to its original condition when the interruption was over?
3. What were the effects of the interruption on the community?

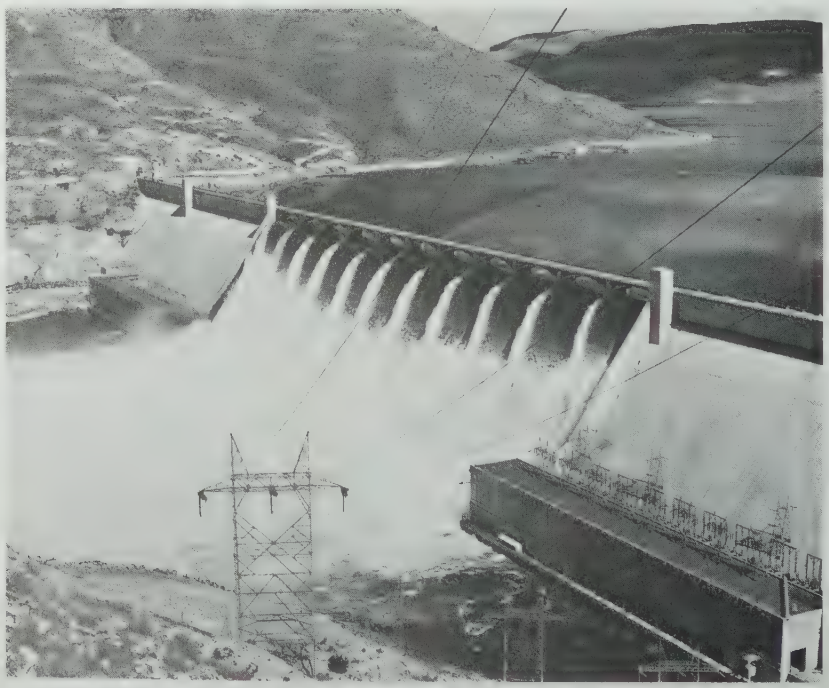
Extend Your View 18-1
Changes in your school

Can you identify changes in your environment? Look around your classroom and identify something that has changed since the school was built. Identify something that has changed since yesterday. How do you know these things have changed?



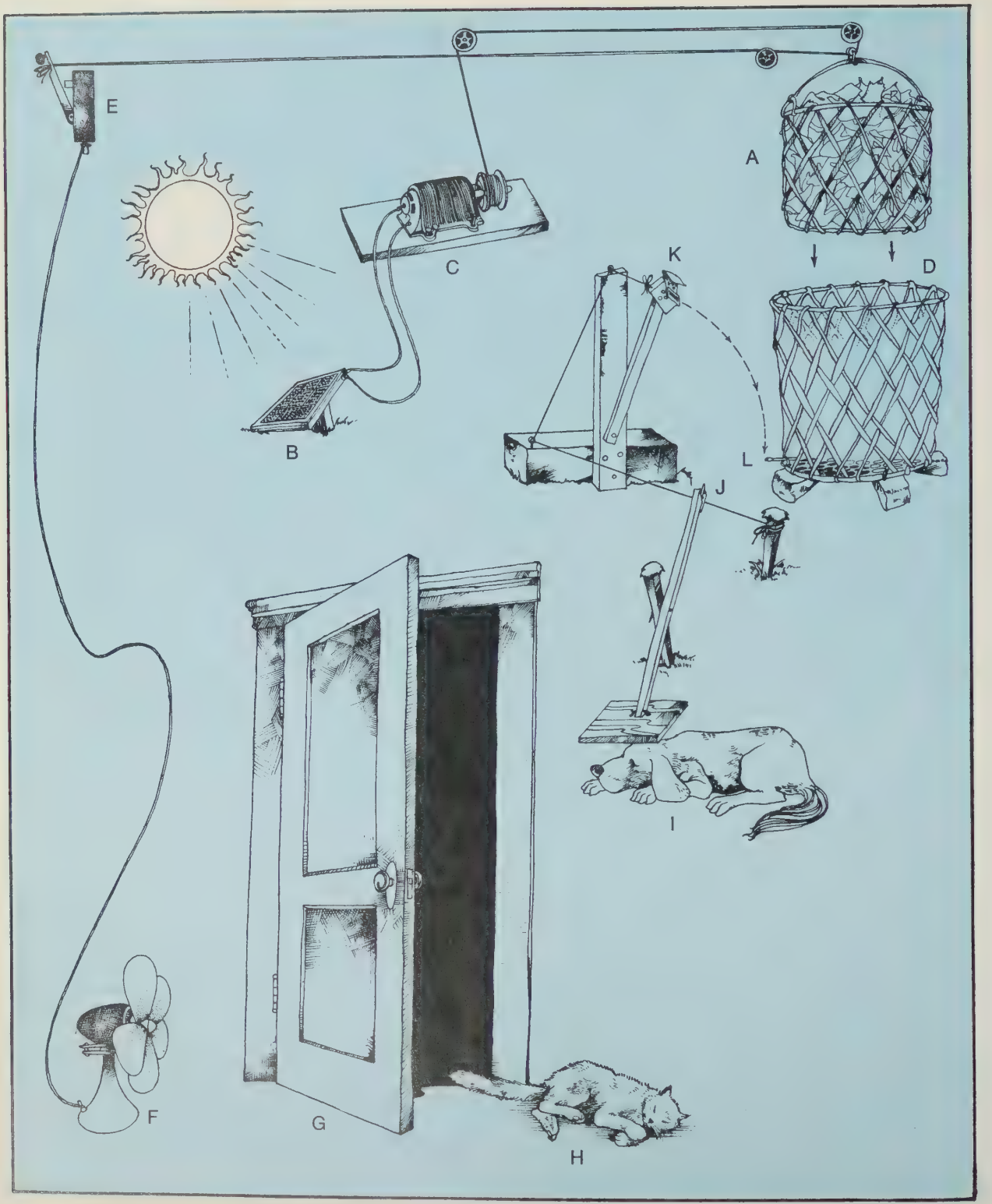


What kind of energy flow has been interrupted in each of these situations?






Strike
Please don't shop here
Local 1100
Local 410
Strike
Please don't shop here
Strike
Please don't shop here
Local 1100
Local 410


E
A
C
K
D
B
L
J
I
F
G
H

Extend Your View 18-2
The automatic sunrise trash burner

Can you identify examples of energy flow and pollution in your environment? The automatic sunrise trash burner operates this way:

1. The night before, the trash is taken outside and placed in the basket (A).
2. As the sun rises the next morning, it shines on the solar cell (B). The solar cell produces electricity which starts a motor (C).
3. The motor, in turn, lowers the trash into the trash can (D).
4. The trash being lowered pulls a wire attached to an electric switch (E). This closes the switch.
5. The closed switch causes a fan (F) to start blowing air.
6. The air blows against an open door (G) causing it to slam on the tail of the cat (H).
7. The howling cat awakens the sleeping dog (I) who raises its head.
8. The dog's head causes the razor blade (J) to cut the string holding the match cover (K).
9. The match cover swings down, striking and lighting the match (L).
10. The match burns down and sets fire to the garbage.

Explain any examples of energy flow that you see in the operation of this system. Do you see any place where pollution is occurring?

Extend Your View 18-3
Lights out

How does the interruption of one form of energy flow affect the environment? On the night of November 9, 1965, there was an electric power failure. It blacked out most of the northeastern United States plus parts of two Canadian provinces. About 30 million people in an area of over 20 million hectares were affected. In New York City alone, over 800 000 people were trapped in subways for hours.

Briefly explain how you think this electric blackout affected the flow of energy. What effects did this situation have on the cities, the people, and the transportation systems?



19

Why is clean air important?

After you complete these Investigations, you will be able to

1. describe some methods for studying air pollution in a community.
2. identify the variables that affect how much air pollution people breathe.
3. use an experiment to show the effects of air pollution on plants.
4. infer, from data, some effects of air pollution on people.

On December 5, 1952, a thick fog rolled in over London, England. Hardly anyone paid attention at first, because the city was famous for its "pea soup" fogs. However, this fog did not burn off or blow away. It combined with smoke from homes and industries to form smog. As moisture, soot, and gases collected, the smog turned from white, to brown, to black. Buses traveled at three kilometres an hour. Someone had to walk ahead to direct the drivers. A performance of the opera had to be halted because the smog seeped into the theatre. The singers could not see the conductor. The audience could not see the stage. After three days, visibility was reduced to less than a metre.

For five days the smog smothered London. Hospitals were packed with people having trouble breathing. The British Committee on Air Pollution estimated that the smog caused 4000 deaths. During the next two months, there were 8000 more deaths than usual. Scientists suspected that these, too, were caused by the killer smog.

Donora, Pennsylvania, was hit by a smog on October 27, 1948. This town is located near the bottom of a steep valley. The fumes from a steel factory, a sulfuric acid plant, and a chemical plant settled down on the town. The atmosphere became horribly polluted with industrial wastes. Street lights had to be turned on during the daytime. Some 6000 of the 14 000 people in Donora became ill, and 20 died from the effects of the smog.

Investigation 19-1
Acid rain in your community

Did you know that the rain that falls on your house, your school, and on you may contain acid? As factories and cars burn fuel they produce gases. Sulfur dioxide is one of the gases formed by combustion. Sulfur dioxide and moisture in the air form "acid rain."

This acid rain may cause a number of problems in the environment. It may prevent some types of fish from hatching. It also may affect the fertility of the soil and the production of food. Even the outside walls of buildings are slowly "eaten away" by acid rain.

In this Investigation, you will find out if acid rain falls on your community. You will collect data from different locations to see if the amount of acid varies. All students will gather data for this survey.

If several classes pool their data, perhaps on the same map, you will have more complete data for constructing inferences or hypotheses.

Materials

map of your community
sampling jar
small test tube and stopper
waterproof marker
*p*H paper
color-key card

Sometimes containers that are identified as a scientific and school project may be less subject to vandalism. Placement of the sampling jars in out-of-the-way places may help prevent jars from being knocked over.

Gathering data

Look at the map of your community. Decide where each group will go to sample the rain. Each group should sample two locations. Try to cover as much of the community as possible. Number the sampling locations on the community map. These steps may help you plan your data-gathering.

If possible, samples should be collected both during the week and on the weekends. You may have to postpone this Investigation until rain is forecast.

1. Take your container to your assigned area. Place it in an open spot where the rain can fall directly into it. Why wouldn't

you want to collect rain that has run off a roof or splashed against a house?

2. After the next rain, collect your sample. Cap the sampling jar tightly. Bring it to your next science class.
3. Place one strip of *p*H paper in a small test tube. Add the rainwater from your sample jar. Stopper the test tube and shake the sample for 60 seconds. Immediately compare the color produced by the rainwater with the color-key card. Record the *p*H number that the color stands for.
4. If it rains often during the time you are gathering data, you may want to take several samples from the same location.

You may want to wait until rain is predicted before sending students out to collect samples. Make sure students collect their samples immediately after the rain, so no other factors affect the samples, for example, CO_2 dissolving in standing rainwater.

The volume of the test tube is not critical. The *p*H paper will give distinct color changes with each 0.5 change in *p*H. Estimating to the nearest 0.25 should be easy.



Acid rain has damaged this statue in Venice.

Analyzing data

The *p*H number can tell you the strength of an acid. The lower the number, the stronger the acid. Table 19-1 gives the *p*H of some common substances. Substances with lower numbers are stronger acids. (Substances with numbers higher than 7 are often called bases.) Rainwater without polluting gases is a weak acid with a *p*H of 5.7. How does the *p*H of your samples compare?

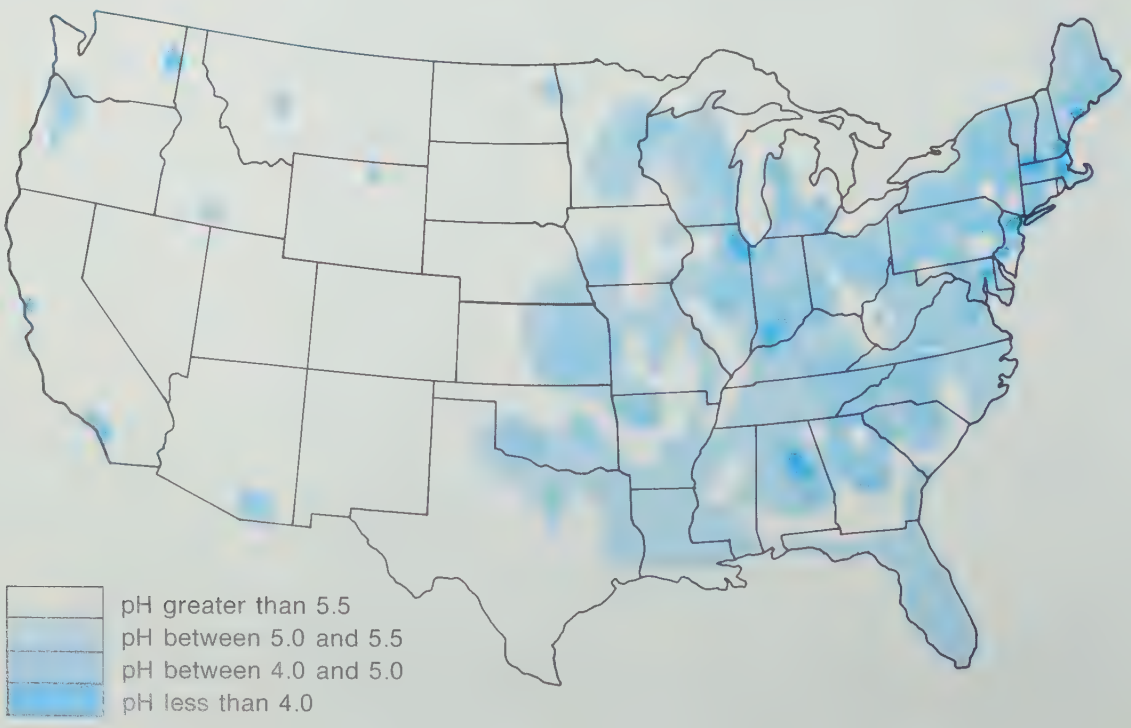
The *p*H of "normal" rainwater is not 7 because of the dissolved atmospheric carbon dioxide.

Table 19-1 *The pH of some common substances*

Solution	*p*H
concentrated sulfuric acid	1
vinegar	3
soda water	4
distilled water	7
baking soda	8
household ammonia	11
concentrated sodium hydroxide	14

1. Was the *p*H of the rainwater the same throughout your community?
2. What are some possible reasons for any differences in *p*H that you observed? How could you test your hypothesis?

Acid rain data from Canada is being collected. There was insufficient data at the time of publication to make a complete North American map.



Investigation 19-2
Airborne particles

Air pollution usually contains particles as well as gases. Smoke contains both. The particles are soot and dust. Usually the particles tend to settle out of the air and land on trees, buildings, and homes. Some very small particles float in the air until they are washed out by rain or snow. Small particles in the air can collect moisture and increase the amount of rain and snow that falls.

How big are pollution particles? Are there different kinds? Can you find out where they come from? Is the number of particles collected the same each day of the week?

Materials
map of your community
glass microscope slides
microscope
clothespins
labels
petroleum jelly

Gathering data

Particles can be collected on a glass slide. Coat most of one side with a very thin layer of petroleum jelly. Leave an uncoated area for picking up the slide. When this slide is exposed to air, particles will stick to it. Later you can observe these particles under a microscope. After you coat the slide, look at it through the microscope to make sure the film is thin enough to let light through.

You will collect samples in one area of your community. Try to collect some samples during the week and other samples over the weekend. If possible, collect samples in one area before and after a rain. The class should agree on what areas to sample. Number the sampling locations on the community map. Take your coated slide to your sampling location. Hang it on a string or clothesline with a spring-type clothespin. Or lay it on a flat surface. Collect the slide after 24 hours. Label the ungreased side with the date, the day of the week, and the number of the location. Put the label near one edge. Observe your slide through a microscope. Are the particles different sizes and shapes? Are they all the same color?

If possible, sample similar areas in both Investigations 19-1 and 19-2. You might want to save the data for comparisons of year-to-year changes.

Compare your sample with those of your classmates. To do this you need to know the average number of particles in an



area of your slide. Without looking through the eyepiece, center the slide on the stage. Focus the microscope and count the number of particles you can see. The area of the slide that you can see at one time is called the **field.** Record the number of particles in the field.

Now move the slide a short distance. Count and record the number of particles in this new field. Repeat this procedure several times. Make sure that you are looking at a different part of the slide each time. Now find the average number of particles in a field.

Compare your number with your classmates'. You should compare only numbers from microscopes that were on the same power. Record your observations on the map of the community. Put down the particles per field, the date, and the day of the week you exposed the slide.

Analyzing data

1. Did you find more particles on weekdays or weekends? Try to explain any differences.
2. Do the locations of residential areas, highways, railroad tracks, industries, farmlands, and dumps affect the amount of particles in the air?
3. Did you observe any differences before and after a rain?
4. From the size, color, and shape of the particles, what can you infer about the particles?

You might want to present a report of your findings from Investigations 19-1 and 19-2 to the rest of the school. Perhaps

the art teacher can suggest how to illustrate your report. Does your data raise questions you would like to ask the people that run your community? One way to get attention is to address these questions to the local newspapers. You can write letters to the editors to make others aware of the problem.

Students could write letters to the local newspapers, prepare displays for local stores, or prepare special features for the school paper.

Investigation 19-3
How much dirt do you inhale?

Clean air is a mixture of invisible, odorless, and tasteless gases. You know that the air also contains gases and particles from industries and homes. Few of us would drink a glass of milk or water that we knew contained these substances.

How much air do you need each day? How much soot and polluting gases are in that air? You can design simple ways to measure the amount of air you breathe in a day. Then you can calculate how much of that air might be pollution.

Emphasize that the amount of air pollution breathed in is proportional to the amount of air inhaled.

Does everyone in the class inhale the same amount? Does exercise affect the amount of air you inhale? Do heavy people breathe in more air than thin people? Think of ways to answer these questions.

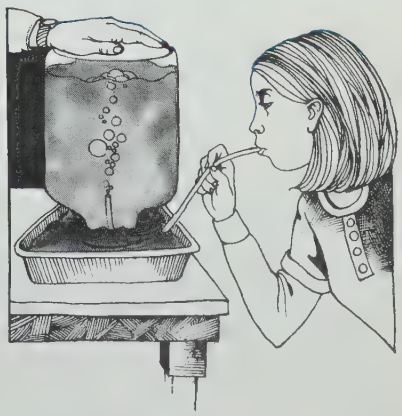
Materials

This setup can be used to measure the volume of a breath of air. Perhaps you can think of other methods.

Gathering data

Design a simple way to measure the approximate volume of air in an average breath. Decide on the method your group will use. Then ask your teacher for the materials you need. Will you need more than one sample? Keep a record of the method you use.

Students will probably decide to use the water-displacement method illustrated to measure the amount of breath exhaled. They may need help to determine the volume of the water displaced.



Now estimate how many times you breathe in a minute; then how many times in an hour, then in a 24-hour day. Calculate the volume of all the air you would breathe in a day. Use Table 19-2 to find out how much pollution is in that amount of air. Use the data from the city nearest yours. Keep a complete record of all the procedures you use and calculations you make.

What variables affect how much air you inhale? Make a hypothesis. Does height or exercise affect the amount? Design an experiment to get any additional data you need. Write down the hypothesis you are testing and the data you collect. Describe any experiments you do.

Table 19-2 *Average air pollution levels*

State	City	Micrograms* of particles/cubic metre of air	Micrograms* of sulfur dioxide/ cubic metre of air
Alabama	Montgomery	61	<5
Arizona	Phoenix	135	10
California	Los Angeles	133	14**
	San Francisco	52	8
Colorado	Denver	152	28**
Connecticut	New Haven	89	40
Florida	Miami	68	<5
	St. Petersburg	43	16
Georgia	Atlanta	79	22
	Savannah	65	7
Hawaii	Honolulu	41	12**
Illinois	Chicago	144	73
Indiana	Evansville	70	19
	Indianapolis	86	11
Iowa	Des Moines	95	7
Kansas	Kansas City	133	8
	Wichita	76	7
Kentucky	Covington	90	19
Louisiana	Baton Rouge	68	10
Massachusetts	Worcester	138	45
Michigan	Detroit	121	12
Minnesota	Minneapolis	61	23
Missouri	St. Louis	109	28
Nebraska	Omaha	112	13
New Mexico	Albuquerque	90	<5**
New York	Rochester	82	22
North Carolina	Winston-Salem	115	12
Ohio	Akron	104	31
Oklahoma	Tulsa	52	<5
Pennsylvania	Philadelphia	115	54
	Scranton	211	30
	York	92	12
Tennessee	Memphis	89	7
Texas	Fort Worth	73	<5
	Pasadena	83	<5
Virginia	Norfolk	75	30
Washington	Seattle	58	24
West Virginia	Charlestown	130	7
Wisconsin	Madison	64	12

*Microgram is one-millionth of a gram.
**These data were not published by the Environmental Protection Agency because minimum sampling criteria were not satisfied.

Analyzing data

Does your data support your hypothesis? Make a short report to the class. Do some people normally inhale more air than others do? What variables seem to change a person's breathing rate? If you moved to Tulsa would you breathe in less pollution? If you moved to Chicago would you breathe in more?

Perhaps the best evaluation of student achievement in this Investigation is based on their reports. Determine if appropriate scientific methods were used and if the conclusions can be legitimately drawn from the data.

Investigation 19-4
How does sulfur dioxide affect plants?

Air pollution may make it difficult to grow plants in or near a city. Many trees cannot survive in city air. Even in areas far from cities, smoke and smog are damaging trees. Pine trees in a national forest 180 kilometres away from Los Angeles are being killed by smog. The smoke from power plants in Maryland kills as many as 300 000 evergreen trees each year. Smog also harms orange trees, lettuce, beets, and spinach.

What happens to the plants? Which parts are affected first? How long does the smoke take to do damage? Try a simple experiment to answer these questions. You will use a common kind of air pollution, sulfur dioxide. It is one of the gases that makes rainwater acid. Most of it comes from burning some kinds of coal and oil. Power plants and heating systems of homes and apartment buildings put a lot of sulfur dioxide into the air.

Materials

at least 2 plants
large plastic bag for each plant
small container
tape
2 g sodium sulfite (a chemical made of sodium, sulfur, and oxygen)
2 ml of 5% sulfuric acid (a chemical made of hydrogen, sulfur, and oxygen)

Sulfur dioxide has a very penetrating odor and is harmful if inhaled in moderate amounts. Care should be taken that the gas is generated only within the plastic bags. Make sure only you add the sulfuric acid to the sodium sulfite. Sulfur dioxide forms sulfurous acid when it reacts with water in the air. Therefore students should avoid prolonged contact with the condensate inside the bag. Dismantle the apparatus yourself. Wear goggles to protect your eyes. Rinse any plants you wish to save. Wash your hands thoroughly or wear rubber gloves.

Gathering data

Record the appearance of each of your plants before the experiment. You can draw or photograph them. Also, describe such things as the color of the leaves and any wilting you see.

If possible, have students take "before" and "after" photographs of the plants. Changes can often be observed within 24 hours. Generally, in a few days the plants lose their bright green color, wilt, and begin to turn brown.



Put one plant into the plastic bag. Set it down on the desk. Measure out 2 g of sodium sulfite. Put the sodium sulfite into a small container. Then put the container in the bag. Sulfur dioxide can be made by adding sulfuric acid to sodium sulfite.

Caution: These two chemicals should be mixed only in a closed container. Do not breathe the sulfur dioxide fumes. Ask your teacher to add the acid to the sodium sulfite.

After the acid is added, quickly seal the bag with tape or a wire tie. Use your other plant to control the experiment. Observe and record the appearance of each plant for two or three days.

Analyzing data

Compare your data with data from classmates who used the same kind of plant. Then exchange data with classmates who used a different type of plant. What conclusions can you draw? Does the kind of plant you used make any difference? Are plants with thick, waxy leaves affected the same way as plants with long, thin leaves? Are young plants more easily damaged than older plants?

If a group sets up an uncontrolled experiment, the time to challenge it is during the analysis of data.

Investigation 19-5
Can air pollution harm people?

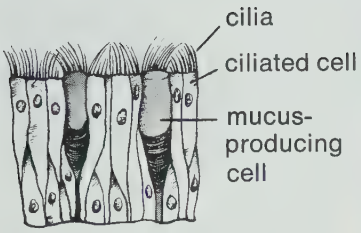
Students who are interested in learning more about human respiration can get information from biology and physiology textbooks.

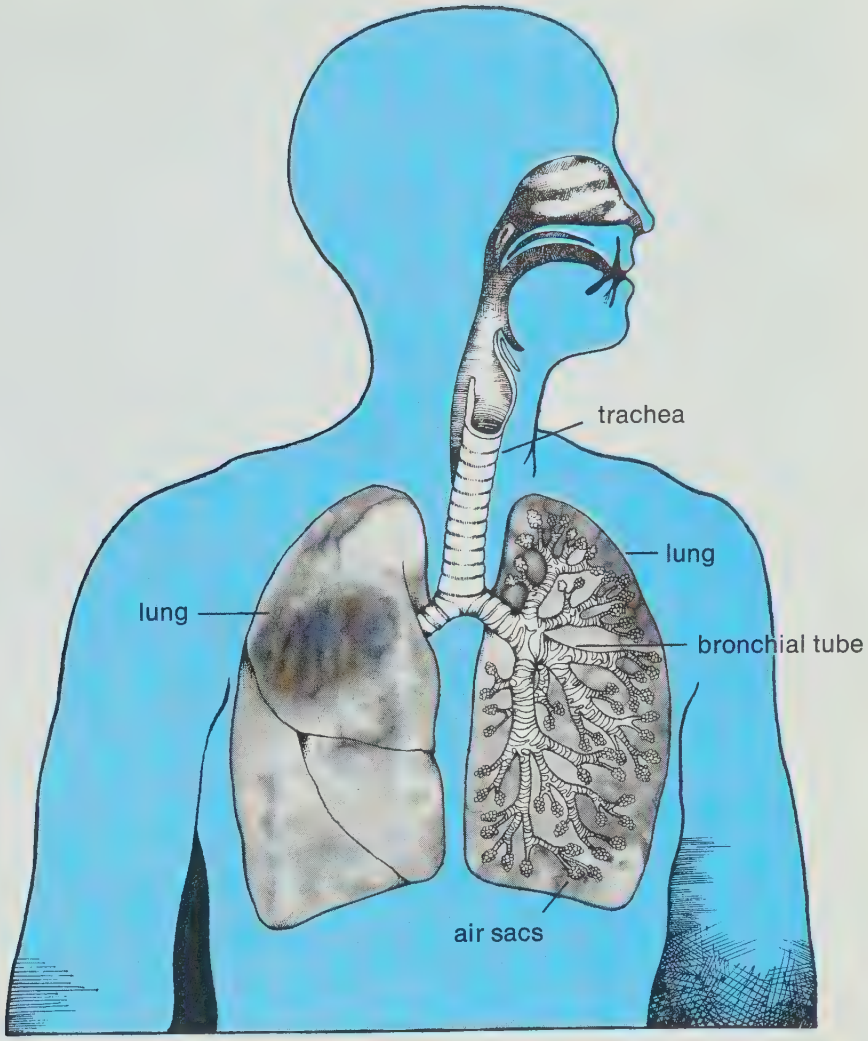
Here is a diagram of the human respiratory system. To understand how pollution might affect respiration you must first know how the respiratory system works.

The large air passages into the lungs branch and divide. Eventually they end in millions of air sacs. These tiny sacs are smaller than the head of a pin. Here gas exchange takes place. Oxygen goes into the blood and carbon dioxide comes out.

The larger air passages are lined with cells that produce a sticky substance called **mucus** (MYOO kuhs). Other cells that line these passages have hairlike parts called **cilia** (SIHL ee uh). These cilia wave back and forth. They push the mucus up through the air passages to the throat where it is swallowed. The stream of mucus is like a conveyor belt. It carries particles out of the respiratory system. Almost 90 percent of the particles inhaled are caught in the mucus.

This cleaning system can be damaged. Sulfur dioxide and smoke can damage the cells lining the air passages. Then so

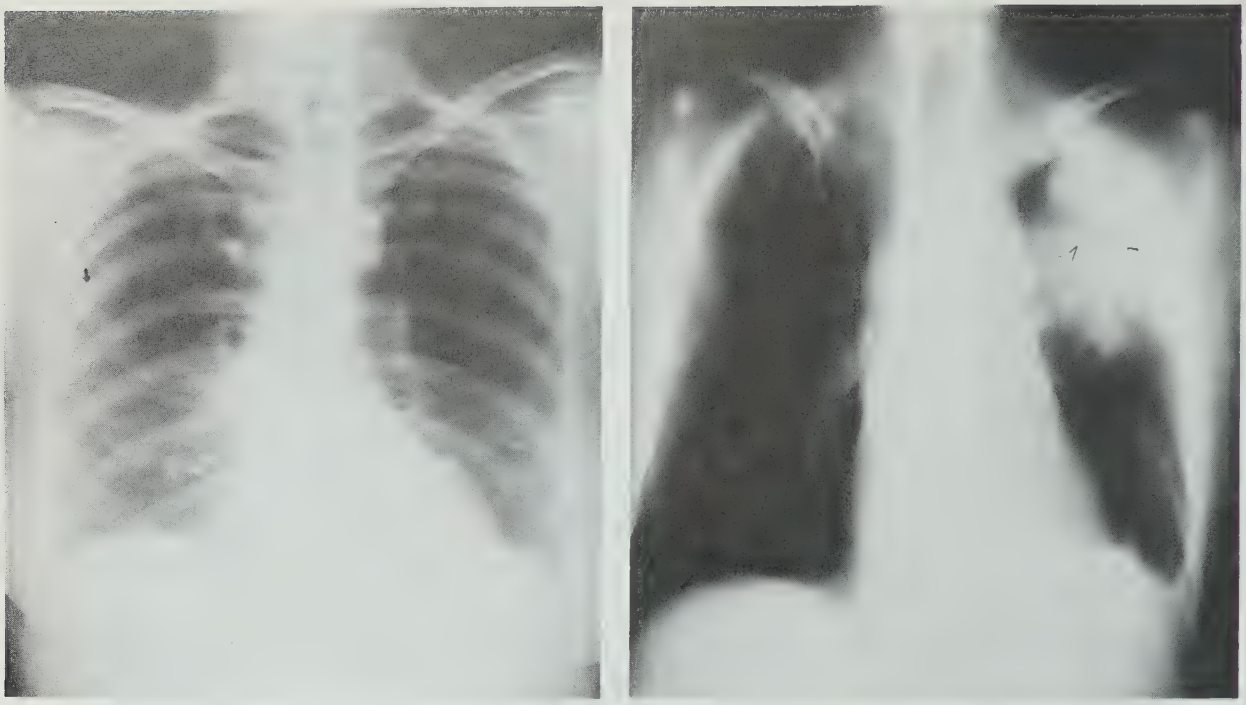




much mucus is produced that it clogs up the lungs. Also particles can collect in the larger passages. The delicate walls of the air sacs do not have any protective mucus and cilia. The air sacs are easily damaged by any polluted air that reaches them.

Statistics show that more and more people in the United States suffer from severe respiratory diseases each year. Emphysema (ehm fuh SEE muh), a crippling disease, is becoming more common. The air sacs in a person with emphysema break down. Their lungs can exchange less oxygen and carbon dioxide than normal lungs. As the disease gets worse, breathing becomes more difficult. The tiny blood vessels in the air sacs shrink and become useless. The lungs are also more easily infected.

The walls of the air sacs break down progressively, reducing the area for gas exchange. The capillaries also degenerate. This places an additional load on the circulation to the lungs. The local blood pressure tends to increase, placing a strain on the heart by making it work harder to pump the blood.



The X ray on the left shows normal lungs. The one on the right shows evidence of emphysema.

Some hospitals are now adding "clean air" rooms for people suffering from severe respiratory diseases. These rooms use special filters and an increased percentage of oxygen in the air.

The exact causes of emphysema are unknown. Damage from sulfur dioxide may be one cause. Cigarette smoking may be another. Some patients suffering from this disease improve when they breathe less polluted air.

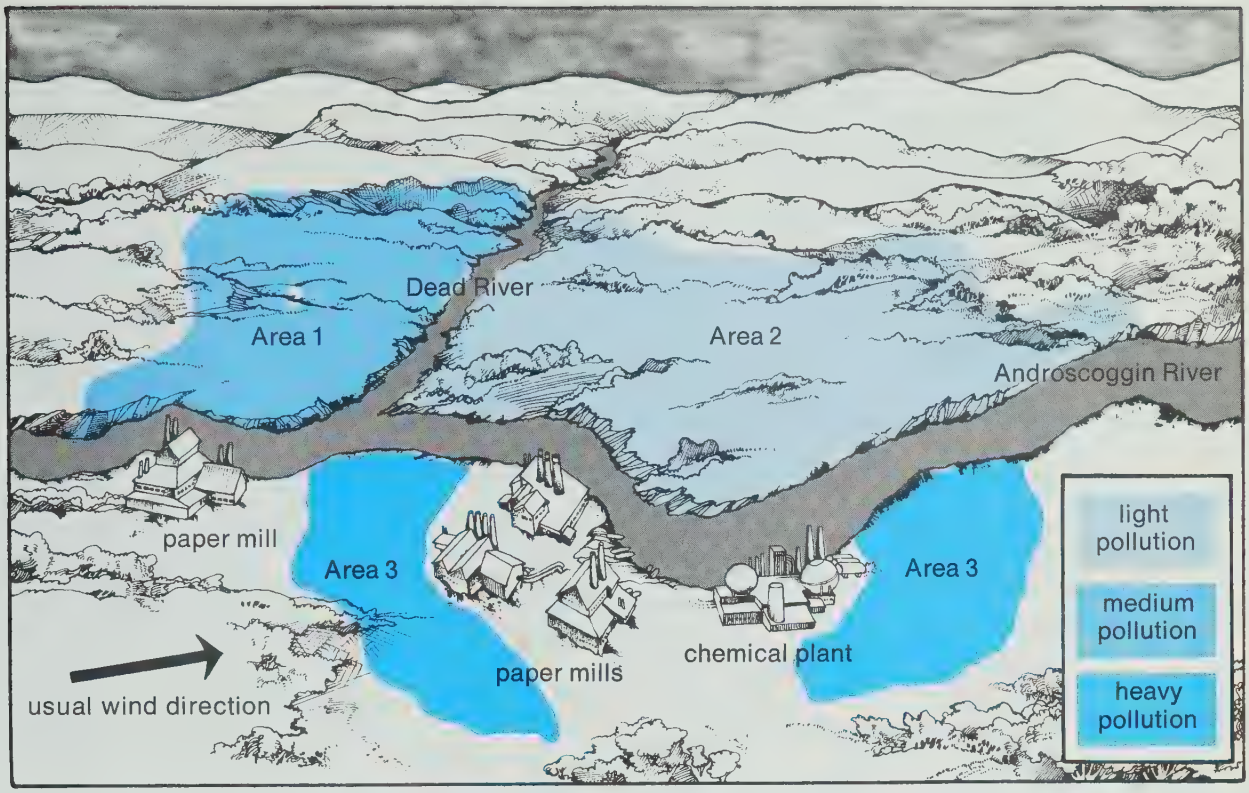
Gathering data

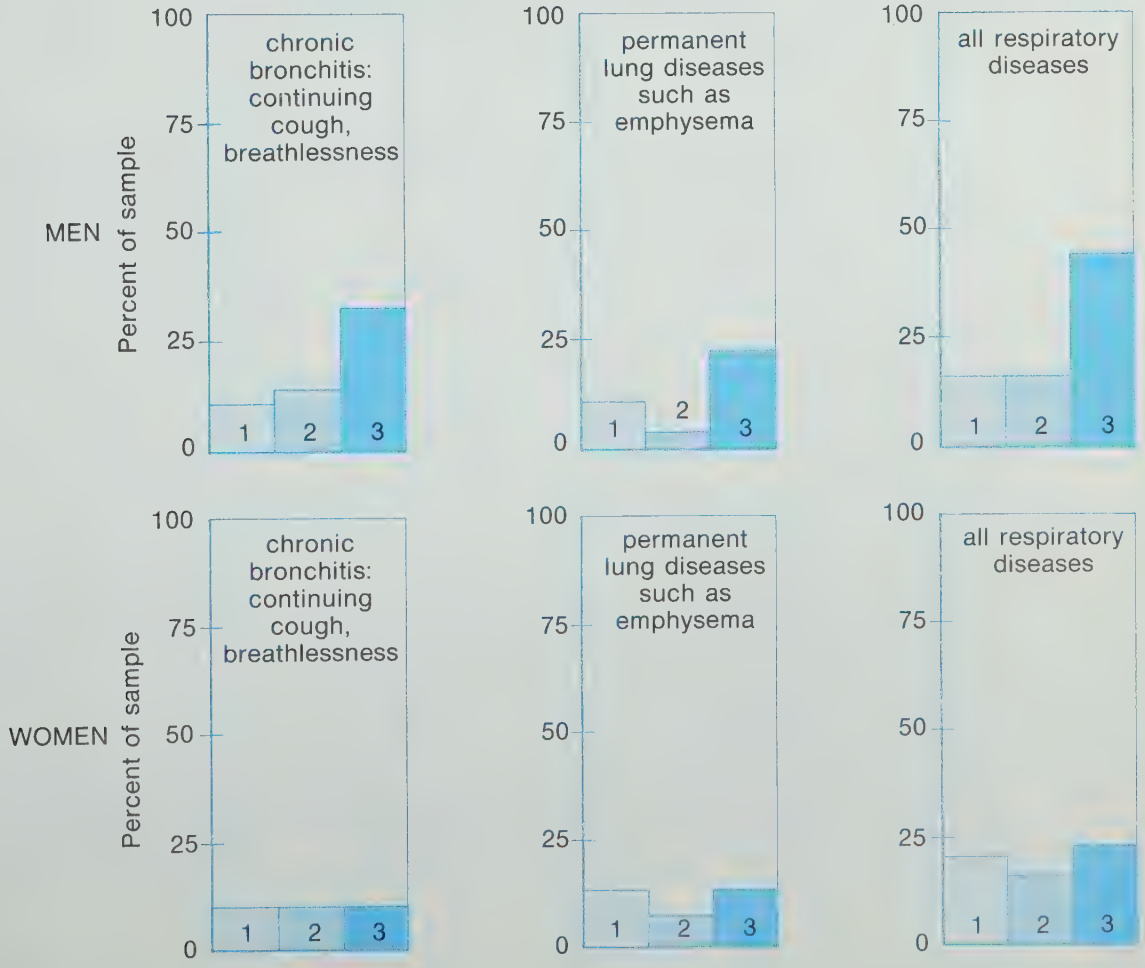
Because of the difficulties in identifying, isolating, and controlling all of the variables, it has been difficult to draw a direct cause-and-effect relationship between air pollution and respiratory diseases. However, most medical authorities agree that such a relationship exists, and they work on that premise.

There is not much data on how polluted air might affect people. Short exposure may cause only watery eyes and mild coughing. It is also possible that air pollution might cause diseases. Or maybe it makes mild diseases become more serious. You be the judge. You can analyze some data collected by doctors in Berlin, New Hampshire in 1961.

Doctors wanted to know if air pollution from factories caused illness. They tried to find out if more people had lung diseases in areas with heavy pollution. The air in the town was surveyed. There were areas of light, medium, and heavy pollution. The doctors then investigated how many people had breathing problems in each area.

Here is some of the doctors' data. The map shows which way the wind usually blew and where the big industries were located. The bar graphs show what percent of men and women in Berlin had a respiratory disease. The people were classified by where they lived. None of the men were smokers.


Dead River
Area 1
Area 2
Androscoggin River
paper mill
Area 3
Area 3
chemical plant
paper mills
usual wind direction
light pollution
medium pollution
heavy pollution


MEN
WOMEN
Percent of sample
100
75
50
25
0
chronic bronchitis: continuing cough, breathlessness
permanent lung diseases such as emphysema
all respiratory diseases
1
2
3

Analyzing data

1. Are men or women more likely to get a respiratory disease?
2. Suppose you and your family were moving to Berlin. What part of town would you want to live in?
3. What else would you like to know about the conditions in a community before moving there?

Extend Your View 19-1
Planning a local pollution study

Can you describe some methods for studying air pollution in a community? Suppose you were moving to a community like the one in Investigation 19-5. How could you bring the map on page 235 up to date? What other data would you collect to describe the air-pollution problem?

Extend Your View 19-2
Inhaling pollution

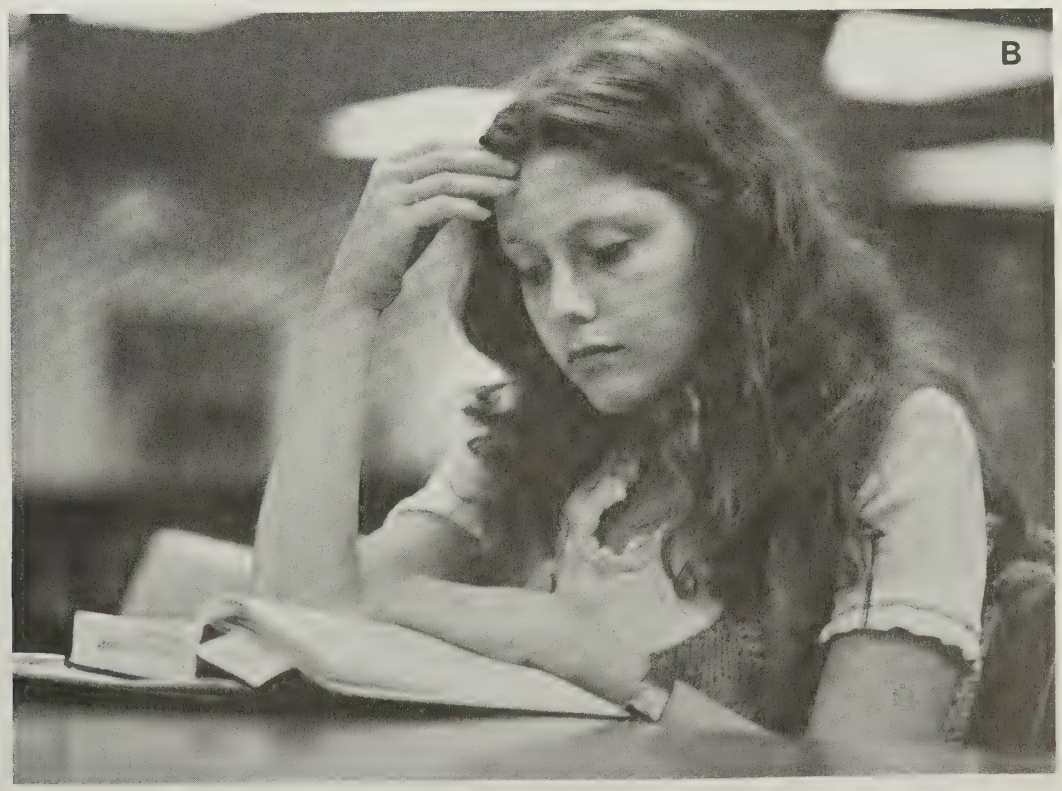
Can you identify the variables that affect how much air pollution people breathe? Look at the photographs on pages 237–239. Who do you think is breathing the most air pollution? List the letters of the pictures, in order, from most to least. Briefly describe the variables in each situation that you used to order the photographs.

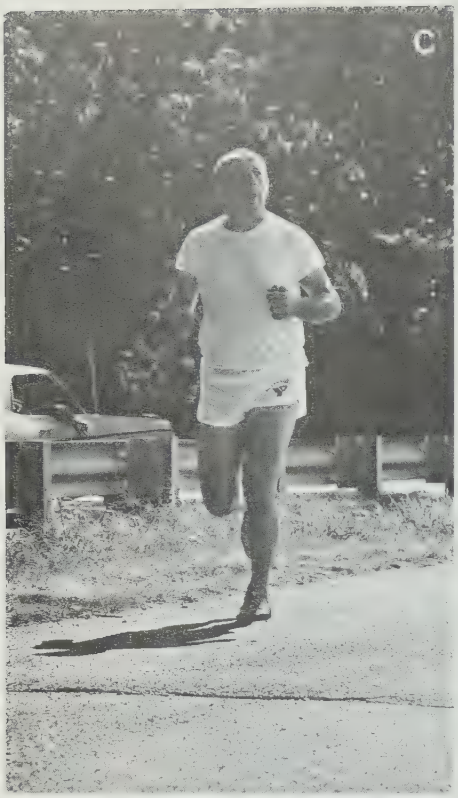
Extend Your View 19-3
Do automobile exhausts harm corn?

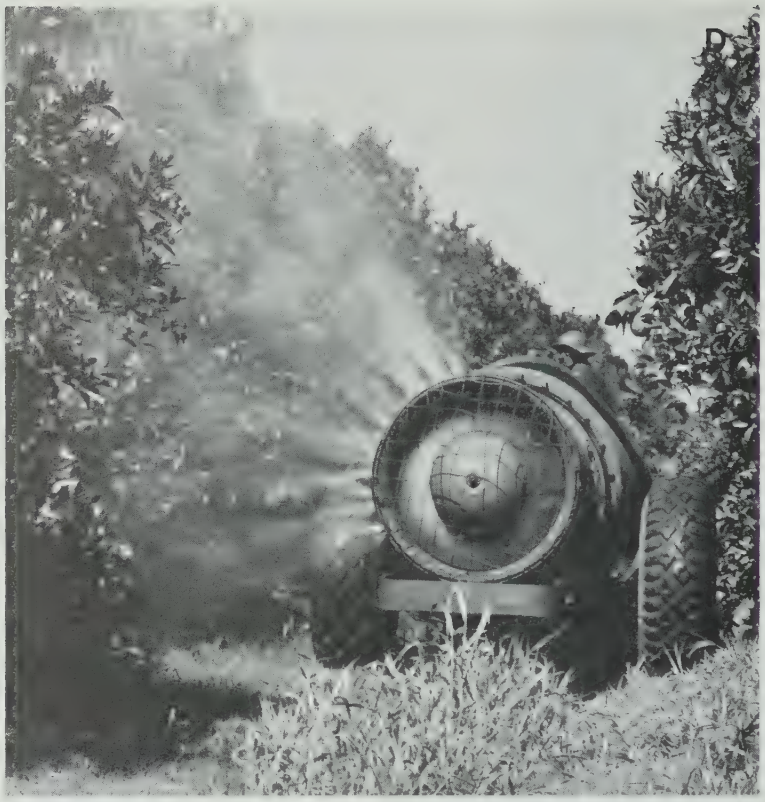
Can you use an experiment to show the effects of air pollution on plants? Some farmers whose land borders highways are worried about their corn. They have read that smog kills trees and crops around Los Angeles. Some of them think that exhaust fumes from cars and trucks are damaging their corn. But they do not have enough evidence.

Design an experiment that could be used to test their hypothesis. Write down the procedures you would follow. What evidence of plant damage would you especially look for? How would you control the experiment?

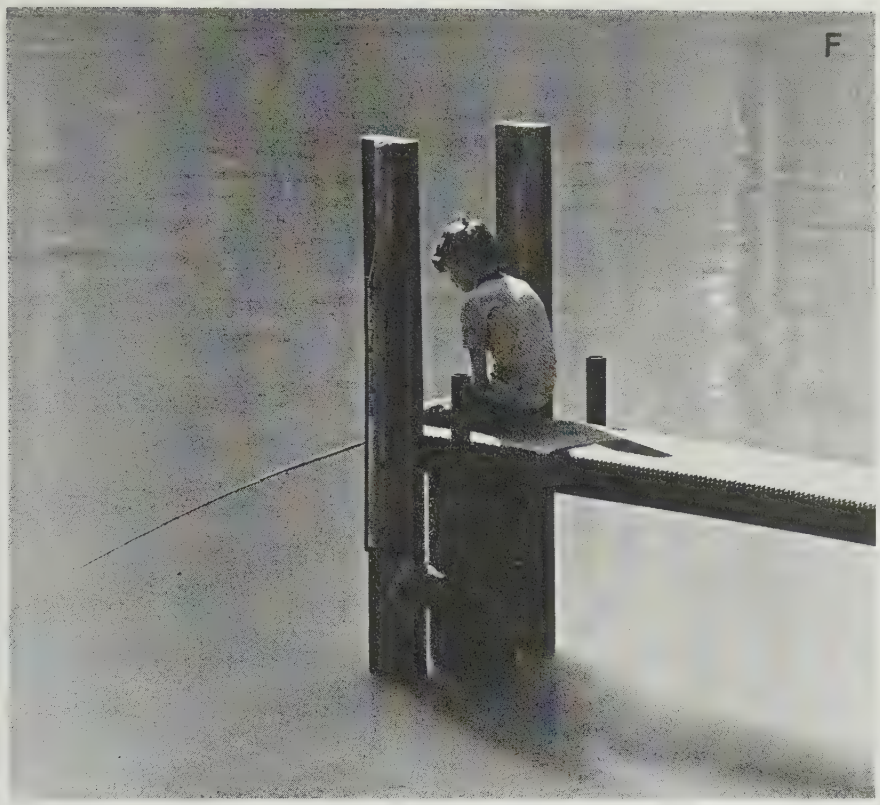

A
DONT
WALK


B


C


D


E


F


G

Extend Your View 19-4

Does smoking cause lung cancer?

Can you infer, from data, some effects of air pollution on people? Not all air pollution comes out of exhaust pipes or brick chimneys. Cigarette smoke is a common kind of air pollution. North American Indians taught the English how to smoke in the 17th century. The tobacco plant did not grow in Europe. At that time the English both praised and blamed the new import.

There was no scientific evidence to support either side. Then in 1939, tobacco was first linked to cancer. Burning tobacco

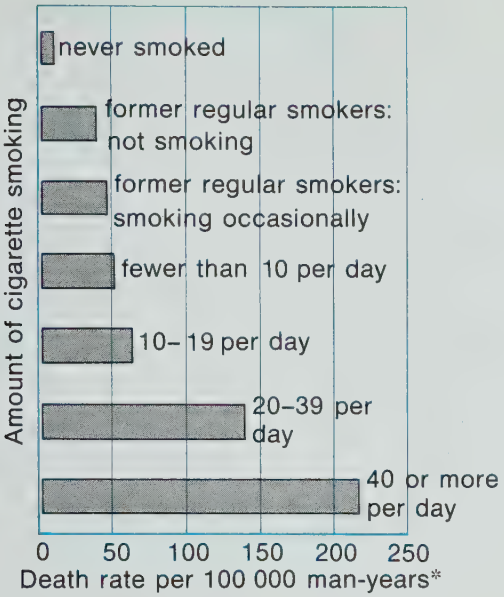
For years, the manufacturers of cigarettes have advertised the pleasures of their products. The American Cancer Society has a different perception of smoking.



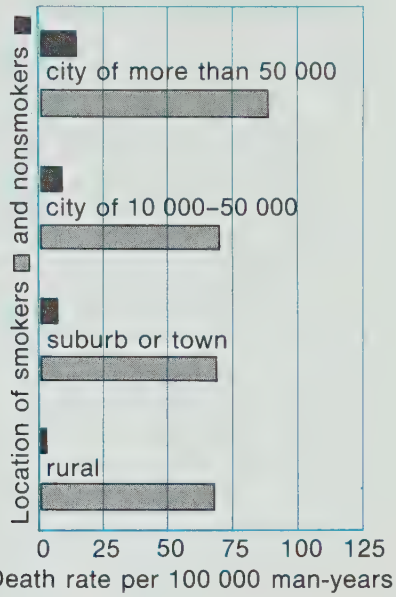


SMOKING IS VERY DEBONAIR

AMERICAN CANCER SOCIETY



*A man-year is data on one person for one year.



produces a thick, black substance called tar. Tars from tobacco were painted on the backs of rabbits. They caused cancer of the skin. But this evidence did not say that people get skin cancer from tars. Nor did it say that tars cause lung cancer.

However, there is data from public health records about smoking and lung cancer in humans. Many doctors are convinced that this data indicates that smoking cigarettes can cause lung cancer. Some of this data on smoking is presented in these graphs. Analyze the data. Does it support the hypothesis that lung cancer is related to smoking?



20

How is Lake Erie changing?

After you complete these Investigations, you will be able to

1. find patterns within a data bank.
2. decide what variables might contribute to the aging of a lake.
3. evaluate plans for reducing the pollution in a lake.

Until a few years ago, Lake Erie meant little to most people in North America. Today Lake Erie has become a symbol of water pollution. It is used as an example of what can happen when people are careless about getting rid of wastes.

Some people who have lived near Lake Erie all their lives say that the lake has changed a lot. They say that it never used to smell bad. But it sometimes does now. Are these people right? Most people who talk about "the good old days" forget many of the unpleasant things that happened back then.

Newspapers and magazines have said, "Lake Erie is dead" and "Lake Erie is a big open sewer." They may have exaggerated the facts. They may want to scare people into stopping the pollution. Most people who visit Lake Erie for the first time are surprised. They find that the water is not "solid" with pollution, and lots of edible fish are still caught. Is Lake Erie really changing? Just what is happening to Lake Erie?

There is genuine cause for concern about environmental quality. However, in the case of Lake Erie many people have gotten emotionally involved without really understanding the problem.

Investigation 20-1
What is happening to Lake Erie?

Students should have a chance to browse through the data bank and decide which data they want to work on. Each student should consider at least two entries. A short class discussion about Entries 1 and 2 is worthwhile to assure that everyone understands the topography of Lake Erie.

Scientific data might help you to decide exactly what is happening to Lake Erie. Some quantitative data has been collected over the years. It is not nearly enough to give a complete answer, but it should help. You may find data that gives at least part of the answer to the question, "What is happening to Lake Erie?"

Gathering data

To avoid confusion, have students work with one entry, or a part of one entry, at a time. Students should not feel that they must "master" a great quantity of data. The object is to find a pattern in raw data and to see if the data relates to the problem being studied. Students should also not feel that they must come up with a predetermined set of conclusions.

On the following pages, you will find a data bank. Choose one or more entries to study. Nobody is expected to study all of the entries. Your teacher may have some additional data on Lake Erie that you could use. Everyone in the class should first look at Entry 1 and Entry 2. These data are about the location and size of Lake Erie.

Analyzing data

Try to find a pattern in each entry you have chosen. Also try to find patterns between entries, if you study more than one. Before you begin, look at this sample piece of data. Check to see that you know how to analyze it.

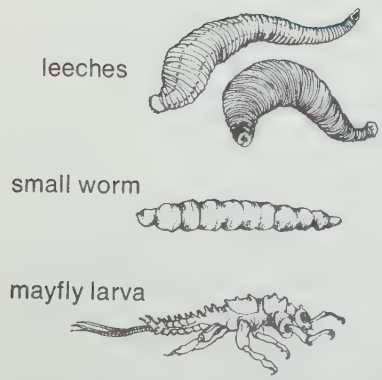


Table 20-1 *Sample data table*

Organism	Needs high oxygen content in water	Organisms per square metre of bottom		
		1929	1930	1958
leeches	no	6	4	37
small worms	no	6	3	559
mayfly larvae	yes	312	515	49

The data shows that the numbers of some organisms have changed greatly. In 1958 there were many more leeches and small worms than in earlier years. But there were fewer mayfly larvae in 1958. Can you infer a possible cause for these changes by analyzing the table?

Now study the entry you selected and try to find a pattern. You may want to reorganize or graph the data. That might help you analyze it. You probably have learned that it is not always easy to discover patterns in data. It takes some clever and careful

detective work to find them. This is just what you are challenged to do in this Investigation.

It is possible that some entries in the data bank do not have a pattern in them. It is also possible that some entries do not contain useful information. Is your entry one of these? Be ready to give your reason if you think so.

You will report to the class any pattern you find in your entry. Be sure you have evidence to support the pattern you find. Then your class will analyze all of the patterns to try to find out what is happening to Lake Erie.

It is possible that even with your help a student will not find a pattern in an entry or find a correlation between two entries. Encourage the student to try a different entry. Some of the easiest entries are 4, 6, 7, and 8. Entries 5 and 11 are the most challenging and probably the most revealing. Watch out for conclusions that sound valid but do not reflect the data.

The data bank

Entry 1

A drainage basin is an area that surrounds a lake or river. All the surface water in a drainage basin flows into the lake or river. Within the drainage basin of the Great Lakes all rivers and

Entry 1 *The Great Lakes drainage basin*

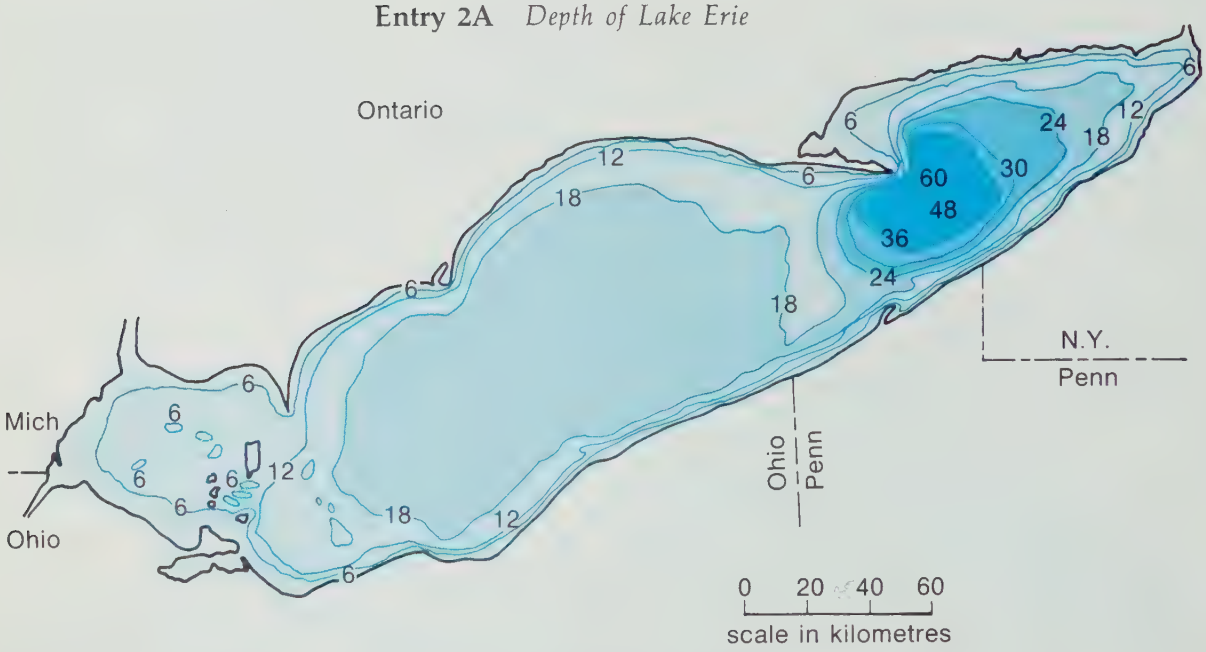


streams flow toward the lakes. Outside the Great Lakes drainage basin, all rivers and streams flow away from the Great Lakes. Many people live in the Great Lakes drainage basin. Look at the cities, states, and provinces that surround the Great Lakes page 245).

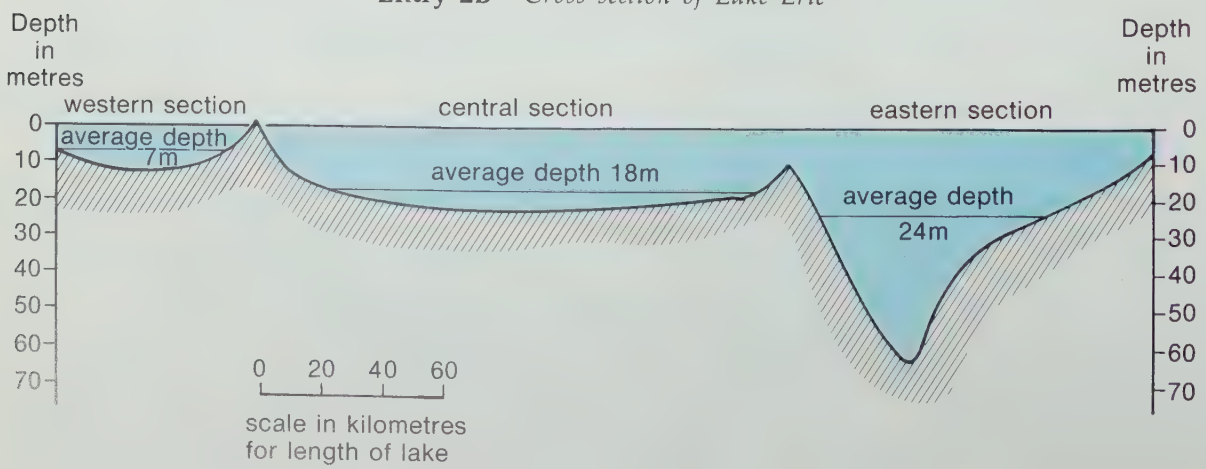
Entry 2

The map on this page is one way to show the shape of the bottom of Lake Erie. The curved lines connect points that are equally deep. The number on each line shows the depth in metres along that line. The darker shades of blue mean deeper water.

Entry 2A *Depth of Lake Erie*



Entry 2B *Cross section of Lake Erie*

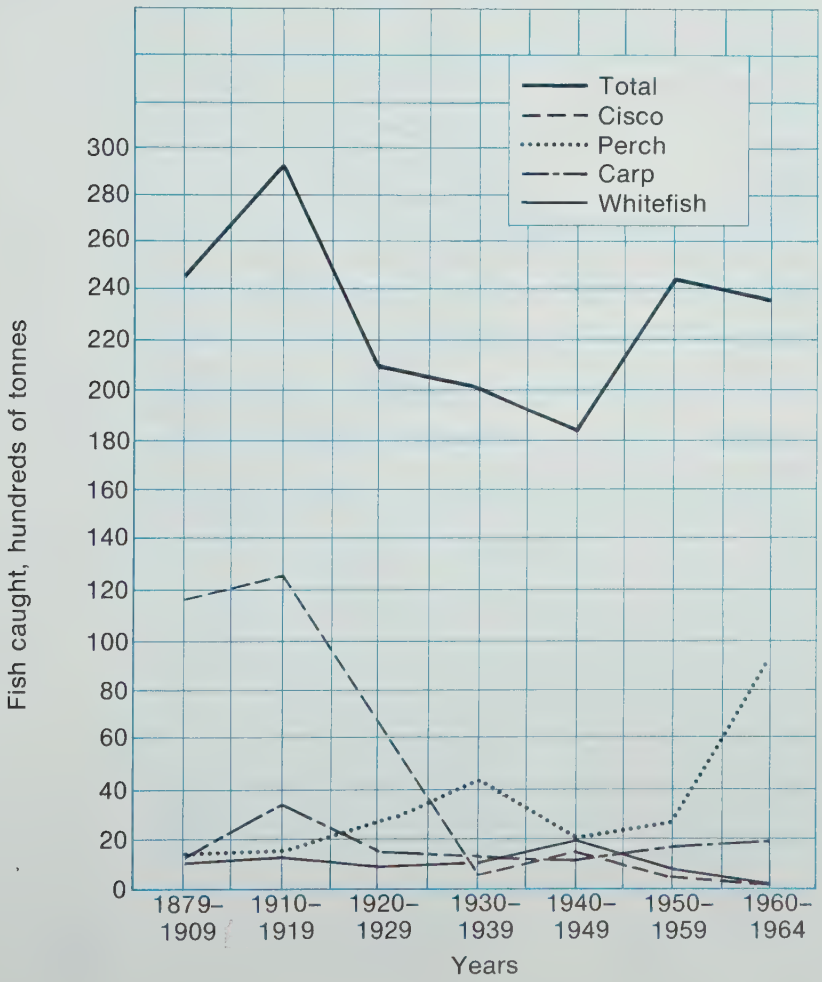


The diagram on page 246 is another way to show the shape of the bottom of the lake. It shows how Lake Erie would look if it could be sliced down the middle and viewed from the side. Notice that in this drawing, the depth scale is very different from the length scale. The depth is in metres, and the length of the lake is in kilometres. Lake Erie has three main sections, called the western, central, and eastern sections. Which section do you think has changed the most?

In the literature, the three "sections" of Lake Erie are called the eastern, central, and western "basins." "Sections" was used to avoid confusion with "drainage basin."

Entry 3

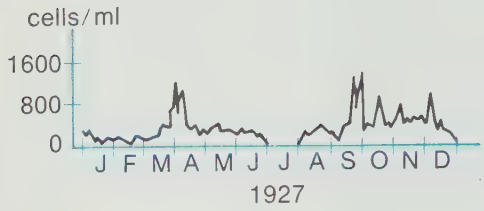
The graph on this page shows the total number of fish caught by commercial fishermen over many years. It also gives information on different kinds of fish that make up the commercial catch. It does not include fish caught for sport. Cisco and whitefish prefer lakes that are deep, cool, and clear. Carp and perch prefer shallower, warmer, nutrient-rich lakes.

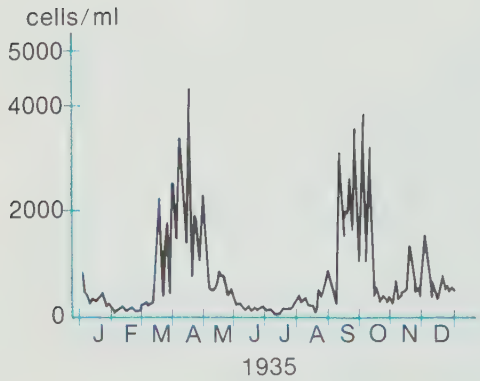


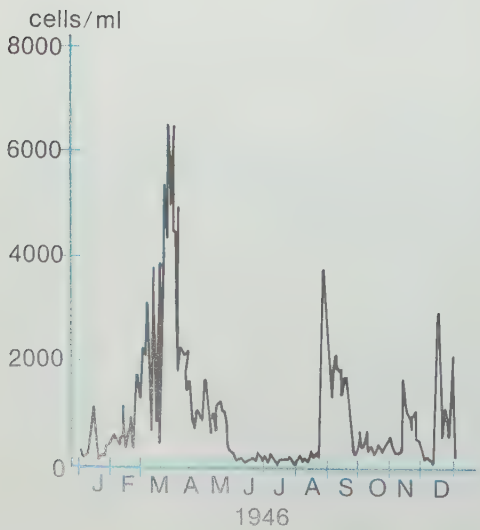
Entry 3 *Fish caught in Lake Erie over many years*

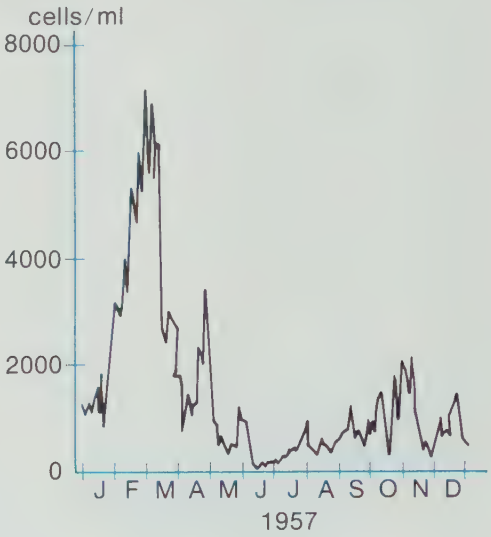
Entry 4
Algae are aquatic plants. Some algae are microscopic and float in the water. These algae are the main food for many aquatic animals. They are the beginning of many food chains.

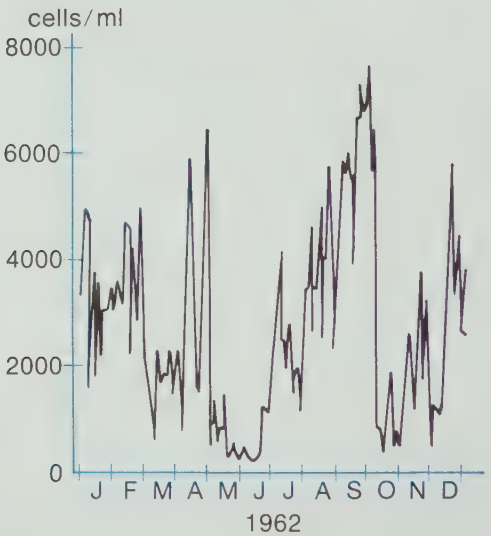
Entry 4 *Algae abundance graphs*

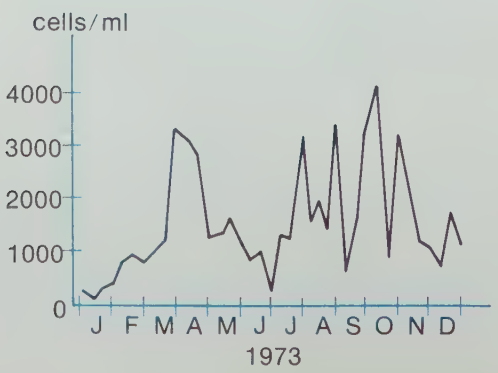












The people in Cleveland drink water from Lake Erie. One pipe that carries in the water extends about five kilometres out into the lake. Every day a sample of water is collected near the pipe intake. A measured amount of the water is placed on a slide under a microscope. The number of algae is counted. The graphs on page 248 show some of the results.

Algae may be more plentiful for two reasons. First, the organisms that eat the algae may be scarce. Second, there may be chemicals in the water that help algae grow very fast.

Entry 5

This is the most difficult entry for a student to comprehend, but it is very important in many ways. Students could work on either or both parts.

All natural bodies of water contain living organisms and dead matter. The dead matter may be dead organisms or human wastes—anything that was once part of a living organism. Polluted water often contains a lot of dead matter. Microorganisms eventually break down all the dead matter. This process of decay uses up oxygen. This may leave very little oxygen dissolved in the water. Then some organisms may not have enough oxygen to live. In fact, the dissolved oxygen may be all used up.

Chemists can measure how much oxygen the decaying matter in the water will use up. The amount of oxygen that will be used up is called the **chemical oxygen demand,** or COD. A lake with a COD of 10 mg/litre will use up twice as much oxygen as another lake the same size with a COD of 5 mg/litre.

The dissolved oxygen in water may come from the atmosphere or from the respiration of aquatic plants. Usually water can hold up to about 20 mg/litre of dissolved oxygen. Imagine that a sample of water contains 20 mg/litre of dissolved oxygen. Suppose its COD is 25 mg/litre. Would the microorganisms have enough oxygen to break down all the decaying matter?

In an "ideal" situation (maximum exposure of decaying-matter surface area and no O_2 replenishment) where the COD is greater than the dissolved O_2 content, the O_2 will be used up in a matter of hours. Surface diffusion and wind and wave action add to the O_2 supply, but the deeper and calmer the water, the less chance this O_2 will reach the bottom waters.

The data in Entry 5A were collected by a research boat. The highest, lowest, and average measurements taken are shown.

The graph on page 250 shows dissolved oxygen data for three different years. Note how the concentration of dissolved oxygen

Entry 5A *Chemical oxygen demand in Lake Erie (mg/litre)*

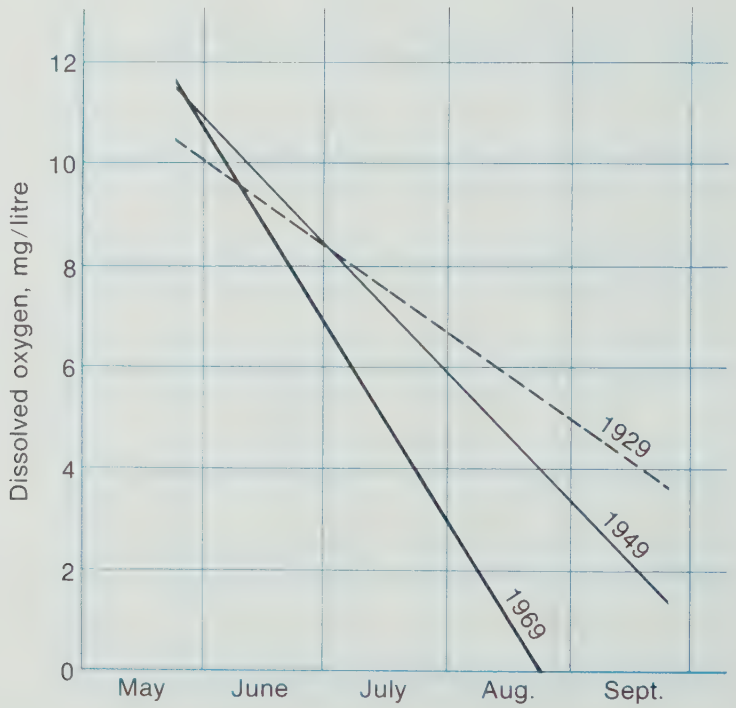
Date	Western section			Central section			Eastern section		
	high	low	average	high	low	average	high	low	average
10/63	10.6	3.5	6.5	8.6	3.1	6.4	20.9	4.7	6.9
5/64	13.1	7.5	10.7	16.0	3.6	8.4	27.0	5.7	8.8
6/64	28.0	4.2	12.3	6.0	5.0	5.5	7.0	6.0	6.1
8/64				9.0	7.0	8.1	13.0	6.0	8.0
9/64	29.0	1.1	12.0						
overall average			10.4			7.1			7.5

changes during the warm months of the year. The samples were taken from water at the bottom of the central section of Lake Erie. This "bottom water" is the water closest to the sediments of decaying matter. The data points on the graph are the average values of samples collected on different dates. The lines on the graph show the patterns or trends for each year.

Normally, every summer, the waters of the central section of Lake Erie are quite calm. There is little mixing between water at the surface and water on the bottom. Usually there is less dissolved oxygen at the bottom of the lake. The surface water gets oxygen from the air. When cold weather comes in autumn, the lake waters mix. The bottom waters then are renewed with oxygen. If the deep parts of the lake run out of dissolved oxygen in the summer, they will remain without oxygen until the waters mix in autumn.

The lake waters mix in autumn because the cold air cools the surface waters, which become more dense. The subsequent sinking of the cool water and rising of the warm water is called the autumnal overturn.

Entry 5B *Dissolved oxygen in the bottom water of the central section of Lake Erie*

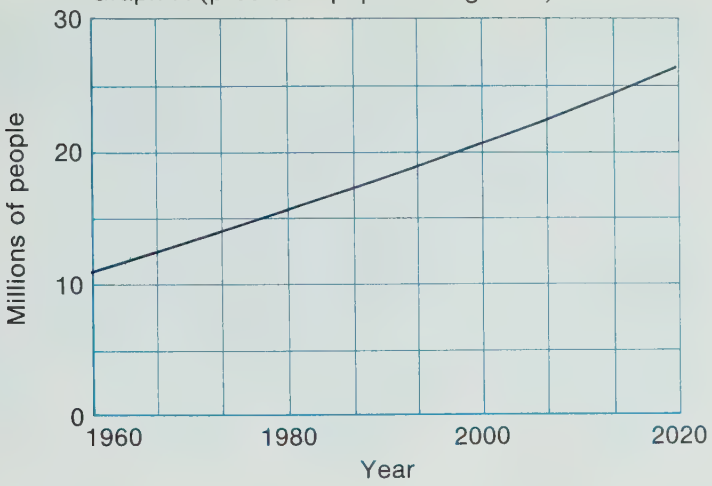


Entry 6

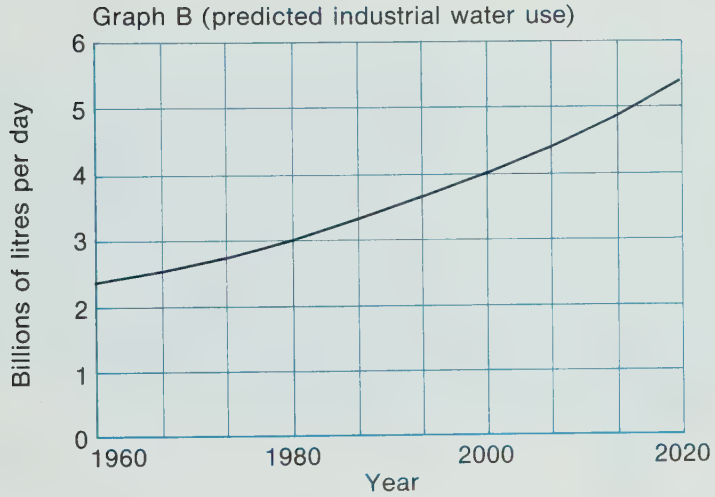
It is predicted that population and water use will change in the Lake Erie region. Graph A on page 251 shows the predicted pattern of population growth in communities of the Lake Erie drainage basin. Graph B shows the predicted water use by industry. Graph C shows the predicted water use in homes.

Entry 6

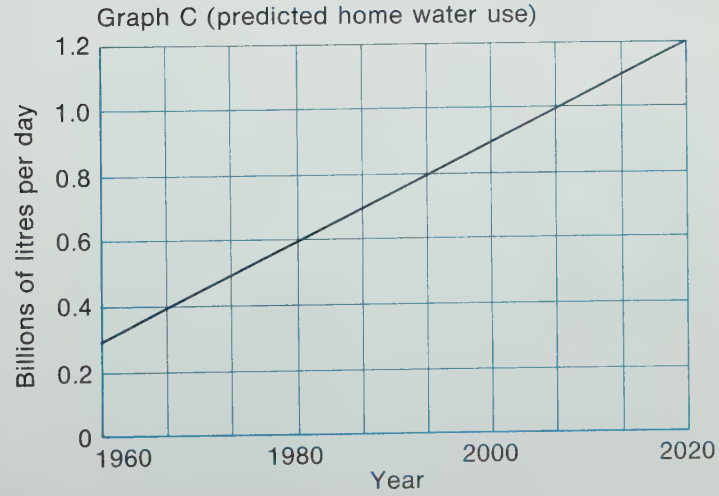
Graph A (predicted population growth)



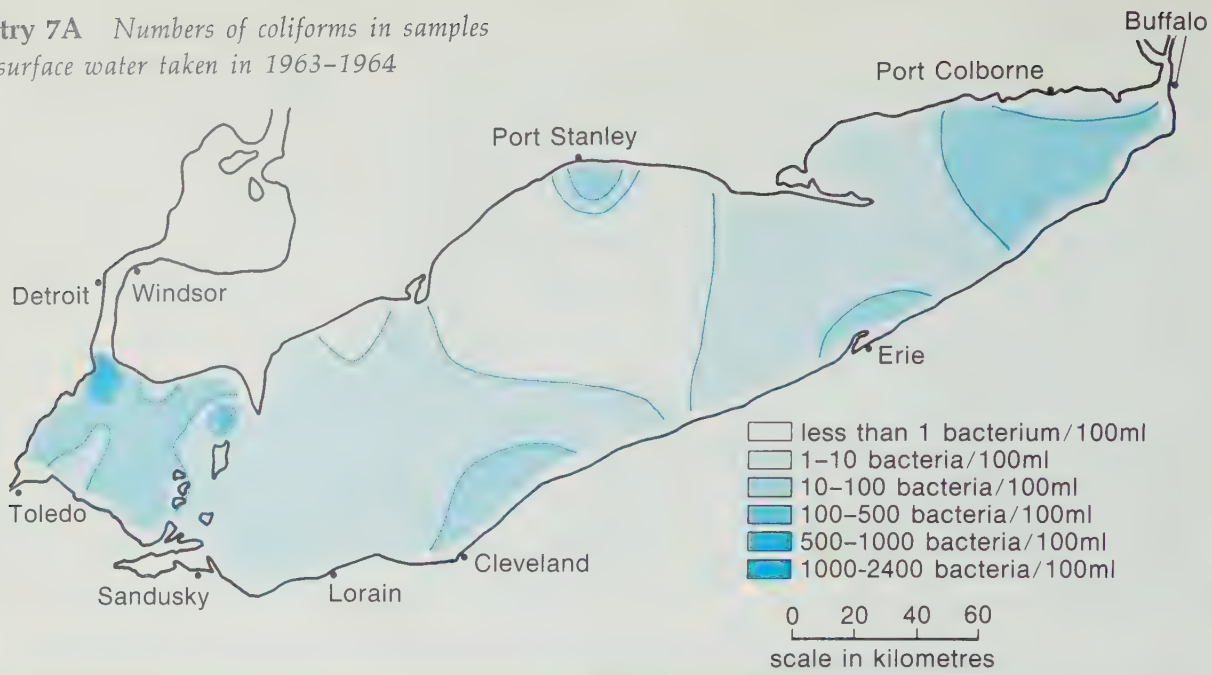
Graph B (predicted industrial water use)

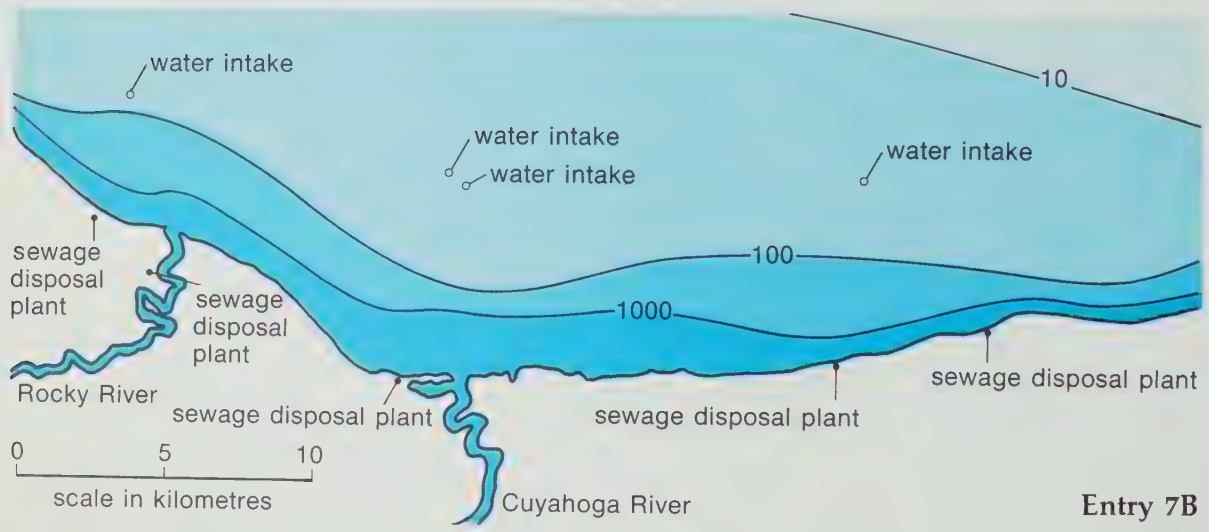


Graph C (predicted home water use)



Entry 7A *Numbers of coliforms in samples of surface water taken in 1963–1964*





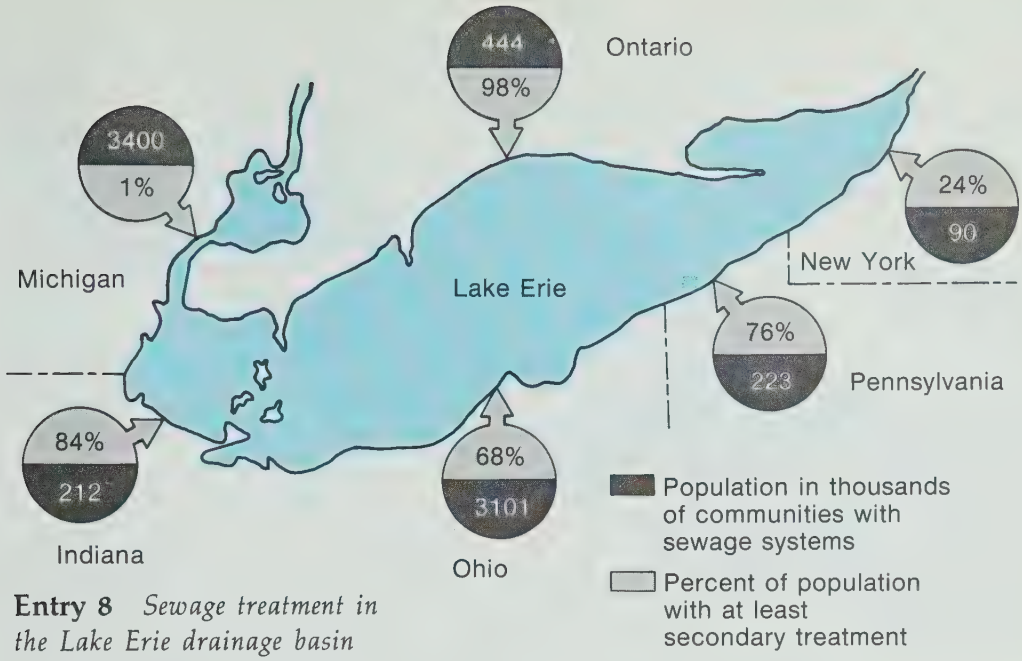
Entry 7B

Entry 7

Coliforms (CAH luh fawrms) are a kind of bacteria found in the intestines of humans. They rarely cause disease. But when they are found in water, it usually means that the water is polluted with sewage. When there are lots of coliform bacteria in the water there are probably many disease-causing bacteria also. This is because the wastes of sick people are also being flushed into the water. In Ohio, water is considered safe to swim in if it has less than 200 coliforms per 100 millilitres of water.

Epidemics of typhoid, cholera, and dysentery can result directly from water polluted with human wastes.

The first map on this page shows the numbers of coliforms in Lake Erie. The second map shows the shoreline near Cleveland. The lines connect places with the same coliform counts. Why are there less coliforms in the middle of the lake?



Entry 8 *Sewage treatment in the Lake Erie drainage basin*

Entry 8

There are two kinds of treatment for sewage before it is poured into the lake. Primary treatment removes only the floating material in sewage. Anything that is dissolved or too small to filter, such as bacteria, goes into the lake. Some places also have secondary treatment for sewage. Secondary treatment makes the waste water from primary treatment much cleaner. Microorganisms are used to break down many undesirable substances.

This map shows the number of people who live in communities with sewage systems. The map also shows the percentage of people whose sewage gets at least secondary treatment.

A field trip or talk by a representative from a local sewage-treatment plant might spark student interest.

Entry 9

The following table shows the number of organisms living on the bottom of western Lake Erie in three different years.









Entry 9 *Bottom-dwelling organisms in western Lake Erie*

Organism	Needs high oxygen content in water	Organisms per square metre of bottom		
		1929	1930	1958
leeches	no	6	4	37
small worms	no	6	3	559
mayfly larvae	yes	312	515	49
midge larvae	no	81	22	257
snails	yes	12	24	7
fingernail clams	no	16	8	55
caddis fly larvae	yes	20	1	3

Source: Hubschman, Jerry H., "Relative Daily Abundance of Planktonic Crustacea in the Island Region of Western Lake Erie." *Ohio Journal of Science*, 1960.



Entry 10 *Flow of surface water in the summer*

The types of animal living on the lake bottom are an indication of the state of dissolved O_2 in the water at that depth.

Scientists study populations of these organisms by scooping up all of the mud, sand, or rocks in a measured area. They dig down about three centimetres. The organisms are removed, classified, and counted. They can all be seen without a microscope.

Larvae (LAHR vee) are young insects that are an important source of food for lake fish. Small worms, snails, and fingernail clams are not nearly as good for fish to eat.

Entry 10

The arrows on the map on this page show the usual direction of surface-water flow in the summer. The water does not flow in those directions every day. Also, the data does not tell how fast the water flows.

This is a difficult entry. If students seem totally frustrated, suggest that they compare total phosphorus versus filter color and total nitrogen versus filter color.

Entry 11

Most polluted lakes have a heavy growth of algae. This often looks like a green scum on the water. Parts of Lake Erie have a lot of algae. The exact cause of heavy growths of algae in Lake Erie has been discussed and argued for years. Scientists do not yet agree on the cause.

People have polluted Lake Erie with many substances. Two groups of chemicals are usually blamed for the increased growth of algae: nitrates and phosphates (FAHS fayts). Nitrates are made of nitrogen and oxygen. Phosphates contain phosphorus and oxygen. The data in the table on page 255 is from a laboratory experiment designed to test the effect of these chemicals.

Entry 11 *Growth of algae in selected lake water*

Sample	Concentration of phosphorus (mg/litre)	Concentration of nitrogen (mg/litre)	Color of filters	
			10 days	30 days
lake water alone	0.01	0.42		
lake water plus 4 ml filtered raw sewage	0.07	1.18		
lake water plus 4 ml treated sewage from secondary sewage plant	0.14	1.18		
lake water plus 4 ml sewage plus special removal of phosphates	0.02	1.13		

Source: Vallentyne, J. R., Johnson, W. E., and Harris, A. J. "A visual demonstration of the beneficial effects of sewage treatment for phosphate removal on particulate matter production in waters of Lakes Erie and Ontario." *J. Fish. Res. Bd. Canada,* August 1970.

Samples of water from Lake Erie were collected in November, January, May, and July. They were combined. Test containers were partly filled with a measured amount of the water. Then 4 ml of another liquid was added. These second liquids are described in the table. The table also shows the amounts of phosphorus and nitrogen in each container.

Algae were grown in the test containers at 22°C. One set was grown for 10 days and another set for 30 days. At the end of the growth period, the contents of the containers were filtered through white filters. The filters caught the algae. If only a few algae grew in the water, the filter was light green. If many grew, the filter was dark green. The color of the filters gives a qualitative comparison of the growth of algae.

Entry 12

Homes and industries around Lake Erie use a lot of detergents. Much of it ends up in the lake. Most people use detergents that contain chemicals called phosphates (FAHS fayts). In the 1960's people began to notice high amounts of detergent foam in polluted lakes and streams. They thought that detergents might be causing the pollution. Some communities started to forbid the use of detergents.

"Phosphates" include several different substances, but all phosphates contain phosphorus and oxygen. The "percent phosphorus" data in Entries 12A and 12B is one way to compare data about phosphates. Entry 12A shows the average percent phosphorus in detergents for several years. Entry 12B shows the percent phosphorus in some major brands of detergents in 1970.

Discuss other possible sources of phosphates such as runoff from fertilized farmland and industrial wastewater.

Entry 12A *Phosphorus in detergents sold in the United States*

Year	Detergents (millions of kilograms)	Average percent of phosphorus
1958	1610	7.7
1963	2060	9.3
1967	2360	9.4

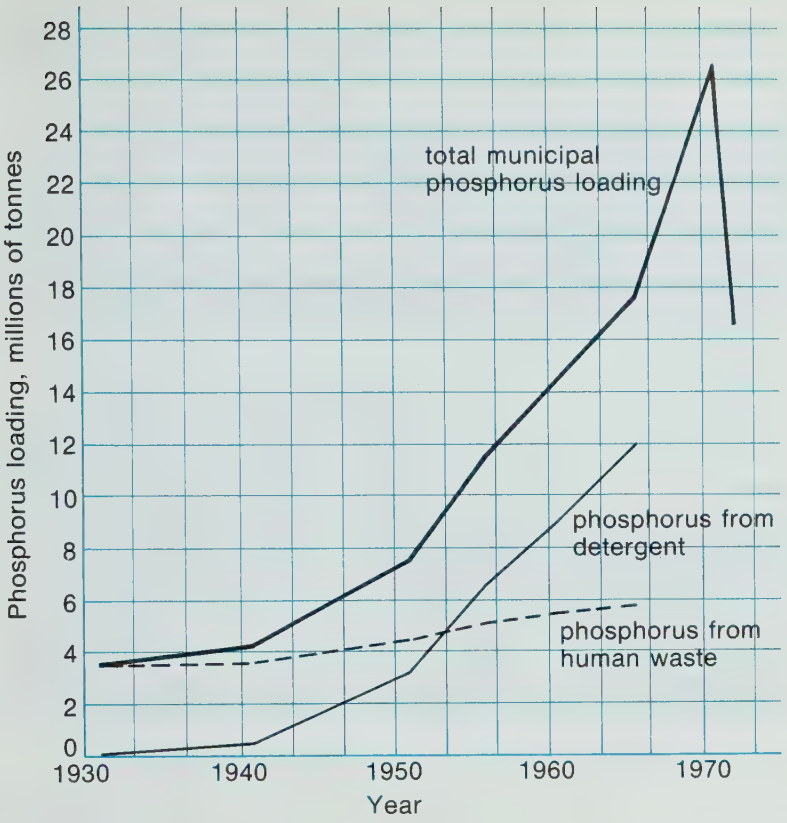
Entry 12B *Phosphorus content in detergents in 1970*

Type of product	Name	Percent phosphorus*
presoaks	Biz	18.7
	Axion	16.0
laundry detergents	Salvo	14.3
	Tide	12.6
	Drive	12.0
	Oxydol	11.8
	Bold	11.5
	Cold Water All	11.5
	Ajax Laundry	11.3
	Cold Power	11.3
	Punch	11.2
	Dreft	10.6
	Gain	10.0
	Duz	9.7
	Bonus	9.5
	Breeze	9.4
	Cheer	9.2
	Fab	8.8
	Diaper Pure	5.0
	Wisk (liquid)	3.6
	Trend	1.8
automatic dishwasher detergents	Cascade	13.8
	All	13.7
	Calgonite	12.5
	Electrosol	8.8

*in the form of STPP, sodium tripolyphosphate

STPP is the major phosphate-containing substance in detergents.

In 1974, laundry detergents available in Cleveland contained up to 8.7 percent phosphorus. Some communities in the Lake Erie basin now have laws about the percent of phosphorus that detergents can contain. Some of these communities have even banned the use of detergents that contain any phosphorus. What percent phosphorus do the detergents have in your community?



Entry 13A *Phosphorus loading in Lake Erie*

Entry 13

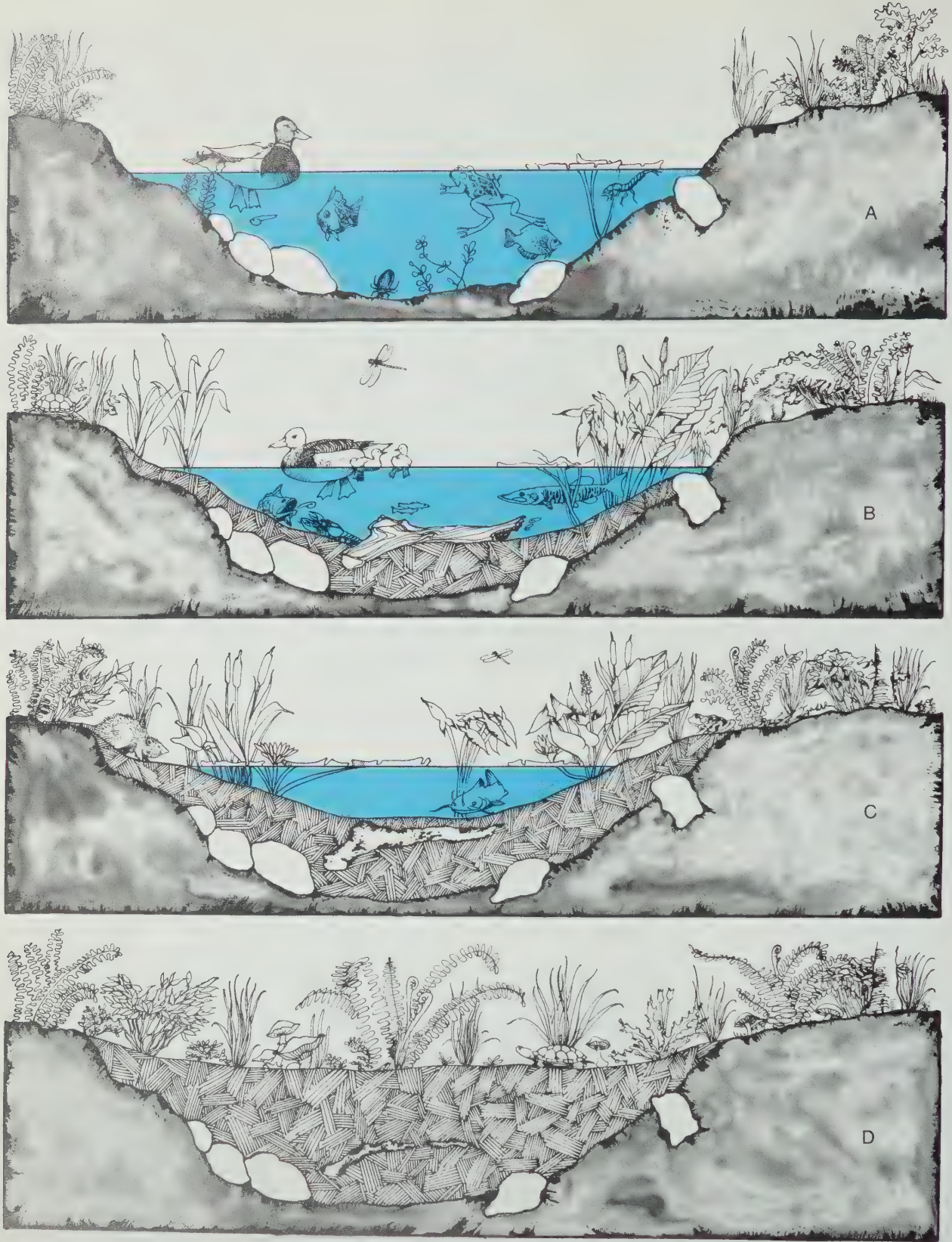
The graph on this page shows the amount of phosphorus dumped into Lake Erie by cities and towns in the United States and Canada. This phosphorus enters the water combined with oxygen in phosphates (FAHS fayts). The top line is for all of the phosphorus. The other two lines show the part of the phosphorus that is from human wastes and the part that is from

Entry 13B *Per capita use of detergent-phosphates (kg/year)*

	1931	1941	1951	1956	1961	1966
Canada	0.013	0.054	0.270	0.495	0.540	0.675
United States	0.018	0.067	0.387	0.675	0.882	1.120

Entry 13C *Population of the Lake Erie basin (in millions)*

	1931	1941	1951	1956	1961	1966
Canada	0.76	0.81	1.0	1.1	1.2	1.4
United States	5.8	6.3	7.6	8.7	9.4	9.8
Total	6.6	7.1	8.6	9.8	10.6	11.2



Using the drawings, describe how this lake changed through the years.

detergents. What do you think caused the drop in total phosphorus loading between 1971 and 1972?

Entry 13B shows the per capita use of detergents over the years. (Per capita means "for each person.") The first number in the table, 0.013, means that in 1931 the "average" person in Canada used 0.013 kilogram (kg) of phosphates in detergents. Entry 13C shows the changes in the population of the Lake Erie drainage basin.

Investigation 20-2
How old is Lake Erie?

Have you ever seen a lake that was so clear and clean that you could see rocks or sand on the bottom? Have you ever seen a swamp or a marsh or a pond with green scummy water? Do you think that the clear lake could ever change and become a swamp? Some scientists think that all lakes slowly grow old and become swamps.

Many kinds of organism live in ponds and lakes. When these organisms die their remains usually sink to the bottom. This dead matter decays, using oxygen in the water. As years go by, more and more dead matter falls to the bottom and decays. Streams that flow into lakes deposit soil from the land. Rain and wind bring particles from the air to add to the sediment on lake bottoms. The sediments on the bottom become homes for more organisms, such as plants, worms, snails, and insect larvae. When these organisms die, they also add to the sediment. A lake continues to change in this way, slowly over the years, until it fills up and a swamp is formed. This is an aging process.

Can water pollution affect the aging process? Water pollution can be classified in two ways:

1. contaminating pollution—this includes bacteria and chemicals that poison organisms.
2. fertilizing pollution—this means nutrients that help populations of organisms to grow faster than normal. For example, phosphates help the growth of algae.

Both of these types of water pollution happen in Lake Erie. Do you think pollution affects the rate of aging in Lake Erie? Does contaminating pollution or fertilizing pollution affect the rate of aging more?

The classification of pollution should make the student aware that not all water pollution is "dirt" or "poison." Some students may still argue that contamination will slow down the aging process by poisoning the organisms in Lake Erie. This happens, to an extent, but fertilizing pollution has a more severe impact on Lake Erie.

The report from *Project Hypo*, a joint Canadian-United States study of Lake Erie (1972) states that if phosphate pollution is stopped immediately, the lake will quickly improve; if not, the rate of deterioration (eutrophication) will be much greater.



Drawing by Chas. Addams; © 1974. The New Yorker Magazine, Inc.

Gathering data

Look at the entries in the data bank again. Also look at the patterns you found in the data in Investigation 20-1. Look for changes in the numbers of organisms. Look for changes in other variables, such as oxygen and phosphates. Look for examples of pollution. Try to find new patterns.

Analyzing data

List the ways people are polluting Lake Erie. Try to decide how pollution is affecting the rate of aging of Lake Erie. Use the data bank to support your answers to these questions.

1. Do you think Lake Erie would be older, younger, or the same age right now if there were no pollution?
2. What type of pollution seems to change Lake Erie the most?
3. If pollution were greatly reduced, what would happen to Lake Erie?
4. How could people reduce the pollution?

The class should discover from the data bank the patterns of increased phosphate input, increased quantity of algae, increased COD, and the influence of pollution.

Extend Your View 20-1
Which lake is more polluted?

Can you find patterns in a data bank? This table gives some data about Lake Erie and Lake Ontario. If you do not know what a particular property means, find the data bank entry that describes it. Try to decide which of these two lakes is more polluted. Use only the data provided. Give reasons for your choice.

Note that although the phosphorus concentration in Lake Erie is small, it is three times the concentration found in Lake Ontario.

Table 20-2 *Properties of Lake Erie and Lake Ontario*

Property	Lake Erie	Lake Ontario
drainage basin (sq km)	86 000	91 000
average depth (m)	17.5	85.0
annual commercial fish catch (million kg)	21.6	0.9
surface temperature (°C)*	10	9
total nitrogen (mg/litre)*	0.6	0.2
total phosphorus (mg/litre)*	0.03	0.01
chemical oxygen demand (mg/litre)*	9.5	6.6
total coliform bacteria (organisms/100 ml)*	12	8
algae (organisms/100 ml)*	12 000	4 000

*Average for the entire lake for one year

Extend Your View 20-2
Is Crystal Lake dying?

Can you decide what variables might contribute to the aging of a lake? Imagine that you live in a city near Crystal Lake. This large lake is a popular recreation spot. One day, the local newspaper carries a front page story with the headline: "IS CRYSTAL LAKE DYING?"

Here is a list of questions about Crystal Lake. The newspaper article answers some of them. Most of the questions are not answered (or asked). Which questions do you think would help you decide if Crystal Lake is aging rapidly?

You do not have to answer the questions, just classify them. Copy the questions on a separate sheet of paper. Do not write in the book. Mark each question either **Y** (yes, the answer would be helpful), or **N** (no, the answer probably would not help), or **M** (the answer might be useful, but more information is needed).

1. How thick was the ice last winter?
2. Are there more dissolved sulfur compounds now than a year ago?
3. Is there enough oxygen dissolved in the lake water to support many kinds of organism?
4. Has the number of water-skiers changed in the past 10 years?
5. How big was the biggest fish that was caught last summer?
6. Does untreated sewage flow into the lake?
7. Are there more algae in the water this week than there were last week?
8. Have some kinds of fish become scarce during the past 10 or 20 years? Have some other kinds become plentiful?
9. Are there bacteria in the lake now?
10. Are there phosphates in the lake water?
11. From what direction does the wind usually blow in August and September?
12. Has the amount of algae in the lake during June and July changed in the past 10 years?
13. Has the number of sport fishermen visiting the lake changed during the past 10 years?
14. Have the kinds of worm and other small animal living on the bottom of the lake changed during the past 10 years?
15. Are the motorboats on the lake bigger and more powerful than 10 years ago?
16. What is the concentration of coliform bacteria in the lake now?

17. What kinds of plant are growing in the lake?
18. Are there any snakes living in the lake or along its shores?
19. Does the lake water ever look extremely green and scummy?
20. Have property values around the lake gone down recently?

Extend Your View 20-3
Can Crystal Lake be helped?

Can you evaluate plans for reducing the pollution in a lake? Pretend that you are the Commissioner of Water Pollution Control in Crystal City. You have three plans to reduce the pollution in Crystal Lake. You must decide which plan to carry out. Each plan will cost the same amount of money and take the same amount of time to complete. Decide which plan is best. Write out the reasons for making your decision.

Plan A
Build primary and secondary sewage-treatment plants for all the cities in the drainage basin. In each plant set up a process to change 90 percent of all phosphates in the sewage into chlorine compounds.

Plan B
Build primary sewage-treatment plants for all the cities in the drainage basin. Build a pipeline to carry all the waste water from these sewage-treatment plants to a large river that flows into the ocean.

Plan C
Build primary and secondary sewage-treatment plants for all the cities in the drainage basin. Ban the use of detergents with large amounts of phosphates. Stop using agricultural fertilizers that contain large amounts of nitrates and phosphates in the drainage basin. These compounds may wash into streams that flow into Crystal Lake.

21

Have our energy needs changed?

After you complete these Investigations, you will be able to

1. explain how energy use is related to the size and lifestyle of a population.
2. discuss some of the variables that influence a decision about a new energy source.

It is often said that nothing is certain except change. Do automobiles look the same as they did ten years ago? Do people dress as they did then? What other things have changed in the last ten years?

Things do not change at the same rate in every place. For many centuries, people have been using water for irrigation. An ancient Egyptian device to draw water is the shadoof. Notice that the shadoof consists of long poles suspended on an upright frame. A bucket is attached to one end and a heavy weight to the other end. The shadoof is still used in many parts of the world.

Changes seem to be taking place at a faster rate. Is it because our population is increasing? Or are people making more demands on the environment?

Investigation 21-1
How much energy do we use?

Since the energy situation rapidly changes, it would be desirable if you could provide up-to-date data on energy use. News about recent local and worldwide shortages can help stimulate discussion. Students can also discuss how their family energy needs have changed over the past few years.

In the winter of 1973–1974, many parts of the world experienced energy shortages. Japan, Europe, the United Kingdom, and the United States had oil and gasoline shortages. Their energy needs grew faster than available energy supplies.

Gathering data

For a complete set of graphs, encourage students to choose different regions.

Table 21-1 shows world energy use. Make a graph of the "total energy use" for at least two of the regions for the three years shown. Make a second graph of the "per person energy use" for the same two regions. Do not worry about the units of energy (joules, J). Just compare the relative numbers.

Table 21-1 *World energy use by regions*

Region	1950		1960		1968	
	Total ($J \times 10^{15}$)	Per person ($J \times 10^{9}$)	Total ($J \times 10^{15}$)	Per person ($J \times 10^{9}$)	Total ($J \times 10^{15}$)	Per person ($J \times 10^{9}$)
Africa	13	6	22	8	33	10
Asia						
Japan	17	21	37	39	87	86
Communist Asia	12	2	65	10	93	12
Other Asian countries	21	3	46	5	80	8
Europe						
Western Europe	174	58	261	78	416	119
U.S.S.R.	84	47	179	83	286	120
Eastern Europe	44	49	80	82	112	108
Latin America	24	15	49	23	80	30
North America						
Canada	27	198	39	217	62	296
United States	342	224	448	248	624	310
Oceania	9	73	14	91	22	122
World*	768	31	1240	42	1897	54

*In 1925, the total world energy use was 44; per person was 23.

Source: *Energy, Economic Growth and the Environment.* S. H. Schurr, ed. Published for Resources for the Future. Baltimore: The Johns Hopkins University Press, 1972.

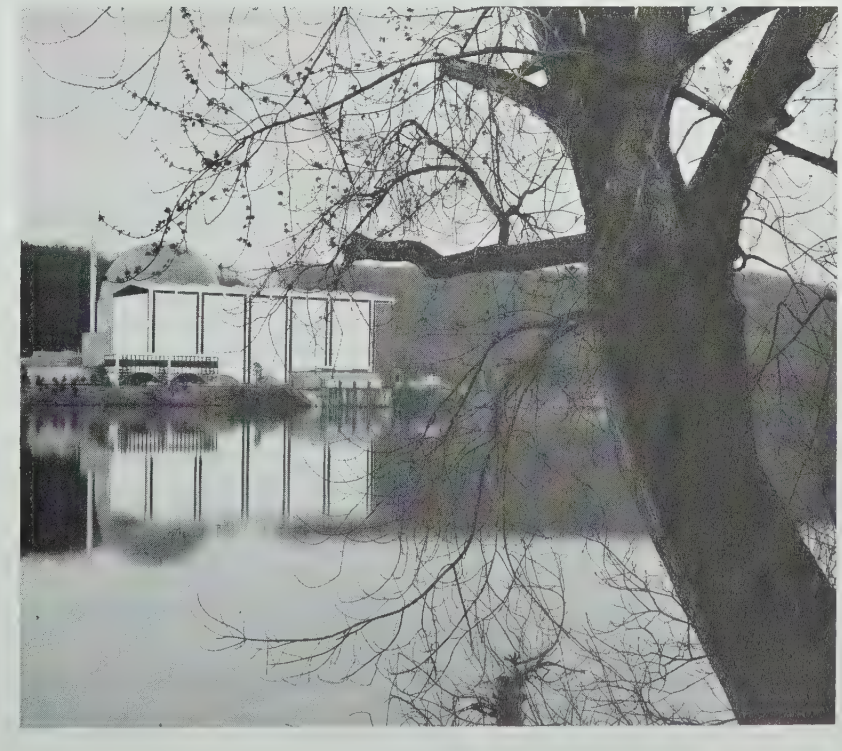
Analyzing data

Compare your graphs with those of your classmates. What trends in energy use did you find? Classify the regions in Table 21-1 by high and low energy use.

1. In what ways are the regions with high energy use alike? the regions with low energy use?
2. Predict the total world energy use in the years 2000 and 2100. What assumptions did you make about population and industrialization?

Investigation 21-2
The nuclear power plant controversy

Central City is a make-believe city. It is typical of many cities because factories have been built there and the people are moving into the suburbs. More industries and more people with their homes, cars, and other energy-using items have created a problem in the Central City area. The problem may become even more serious in the future. The city needs more electricity. But pollution from more power plants may damage the environment.



This nuclear power plant is located on a lake in Connecticut.

The Wattson Electric Company is planning to build a power plant on Serena Lake. Nuclear energy will be used to produce electricity. Most of the energy that is not converted into electricity enters the environment as hot water. This hot water will be piped directly into the lake.

You know that clean water can be polluted by chemicals, sewage, and detergents. Clean water can also be polluted by dumping hot water into it. This is called **thermal pollution.** Table 21-2 shows how organisms are affected by the heat added to a river or lake.

Table 21-2 *A thermal pollution index*

Temperature, °C	Water conditions
21	Normal river temperature. Water is clear. Many kinds of fish, other animals, and plants thrive.
24	No obvious change in water quality or organisms living in it.
26	Almost no fish can reproduce.
26.5	Many desirable kinds of fish, such as trout, have been killed.
29	No swimming is allowed.
32	Most kinds of game fish and most animals that live on the river bottom have been killed.
33.5	Only carp and catfish survive.
35	Unpleasant odors and tastes produced by increasing numbers of blue-green algae. Water not fit for drinking.
40.5	Water can no longer be used by industry for cooling, unless it is first cooled.
43	The river is dead, except for some algae, bacteria and molds.

The company must first get permission from the Site Selection Commission (SSC). Some citizens from Central City do not want a nuclear power plant. Other groups support the power company. The SSC will decide the matter at an open hearing. There are two issues at this hearing.

1. Should the SSC permit the Wattson Electric Company to build a nuclear power plant on Serena Lake?
2. If the plant is built, what method, if any, should be used to cool the hot water?

You will play a role in the controversy. Your goal is to convince your opponents and the SSC to support your position. Use all the data and arguments you can. If you are on the SSC, you will judge the case.

Allow students to volunteer for roles. The number of players elected to the SSC depends on the class size. Five is a good number for a class of 28. An odd number of players will prevent a tie vote at the end of the hearing.

How to play

1. The class elects players to be on the SSC. Your teacher will tell you how many members to elect and how the voting will take place.
2. If you are not elected, you will be assigned one of the remaining roles. Then get together with your classmates who have the same role. Stay together as a group for the rest of this Investigation.
3. Your group should plan its strategy. Find the description of your role on pages 269–274. Read the description and discuss it with your group. You will need to analyze and discuss the data on pages 274–281. Select the data that best supports your position.
4. The SSC calls the hearing to determine what kind of permit, if any, will be granted. You will present your views at the hearing.
5. Choose one member of your group to introduce your group and present its position at the opening of the hearing. He or she will have two minutes for the presentation.
6. After each group has stated its view, the groups will take turns arguing their cases. There will be enough turns to allow all members of your group to speak.

Suggested group sizes for class of 28:
Wattson Electric Company Officials—4
Central City Industrial Association—4
Majority of City Council—4
Committee to Save Serena Lake—5
Minority of City Council—3
Friends of the Environment—3
SSC (already elected)—5

This is one of the most important stages of the Investigation. To devise a logical and effective strategy to influence the SSC, each group must have a good understanding of its role. The players in each group must also be able to find the appropriate data in the data bank to support their position. Knowing the rules of the hearing should help students plan how to play their roles.

Site Selection Commission

You will hold a public hearing on the Wattson Electric Company's power plant. You will decide if the company should build a new plant on Serena Lake. You will also decide if the company can release heated water into the lake. Like most citizens, you are concerned about the quality of your environment. You feel that everyone has the responsibility to keep the lake as clean and unpolluted as possible. Yet, you realize that some means of electric production is necessary. Study the data on pages 274–281 to understand the position of each group. The data will also help you ask useful questions.

One of the members of this Commission will act as moderator for the hearing. The moderator calls the hearing to order and introduces himself and the other SSC members. The moderator also states the reason for holding the hearing.

The hearing should be conducted as completely as possible by students. However, you should enforce the SSC rule that only one group may speak at a time.

Introductions serve only to identify the players and their positions. The SSC is instructed not to allow positions to be challenged at this time.

Then the moderator asks one player from each group to introduce the group and state briefly its position. Allow just two minutes for each group. Call on the groups in this order:

1. Wattson Electric Company
2. Citizens Committee to Save Serena Lake
3. Central City Industrial Association
4. Friends of the Environment
5. Majority of city council
6. Minority of city council

Look for the kinds of behavior that will help you infer outcomes, perhaps subtle and not predicted, of this hearing. For example: What do students say or ask about values or attitudes? Are statements that defend or challenge viewpoints based on data, emotion, or values? Do students refer to their findings from Investigation 21-1?

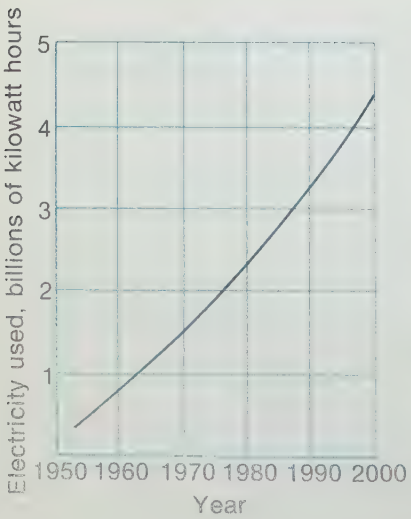
Next, call on each group in the same order to support its position. Allow each group about three minutes to present data. SSC members may interrupt to ask questions at any time. (Do not count the interruptions for questions as part of the three minutes). Let the groups for and against the permit take turns challenging each other's positions and defending their own. They can have up to four turns each.

After the debate, give each group a chance to make a final, two-minute statement. The SSC members should meet privately to reach a decision. This step can take up to 15 minutes. The moderator then reports the decision to the groups. The reasons for the decision should be explained. Then adjourn the hearing.

Wattson Electric Company

You are convinced that nuclear power is the key to a vast new supply of electricity without pollution. You are convinced you should build the nuclear power plant on Serena Lake. You consider your company's main goal to be to provide the best service for the greatest number of people. You want to provide enough electricity for all your customers at the lowest possible price. You also feel responsible to the company's stockholders. The nuclear power plant will add to the company's profits.

People in the area are using more electricity than your plants now produce. Every year they have more appliances, such as air conditioners, dishwashers, electric stoves, toothbrushes, scissors, and can openers. Many new homes are being heated with electricity. The demand for electricity keeps growing.



The graph shows the electric power needs for Central City. The predictions were made by the Federal Power Commission. The average family of five now uses 5000 kilowatt hours a year. Your company has been forced to buy electricity from other power companies to satisfy customers' needs. It cannot continue to do this.

Serena Lake has been studied for two years. You think the study shows that Serena Lake is a good place for the plant. For

example, there is a large enough supply of cold water to cool the steam turbines.

You agree that heat released from the plant will cause some changes in the lake. But the increase in the average summer temperature of the whole lake will only be about 0.5°C. Therefore, the lake will not be harmed.

Your company is studying possible harmful effects to the lake. If the research clearly shows such effects, you would change the design or location of the plant to avoid doing harm. Data is being gathered at the coal-burning power plant already operating on Serena Lake. You are convinced that this data supports your plans for the nuclear plant.

You do not want to build a cooling pond or cooling towers for your plant. The land around the lake is too hilly to build a cooling pond, and the towers are big and ugly. There is no data on the effects of large cooling towers in areas with long, cold winters. The towers might create fogs in the area. In fact, if you are forced to use such a cooling system, you may decide to build the plant in another area.

You are very concerned about a delay in getting the plant built. A delay of as little as a year could increase costs by as much as 30 million dollars.

Citizens' Committee to save Serena Lake

The Citizens' Committee was formed about a year ago. It has more than 200 members. Many of them enjoy outdoor sports. Some are members of conservation groups.

You know that Central City needs a new power plant but you are opposed to the nuclear plant. You think it will heat the lake too much. You are sure the heat will speed up the aging process of the lake. Your data shows the harmful effects of heating on an aquatic environment. You argue that it might not be possible to correct the damage once it occurs. You want no heat added to Serena Lake unless the Wattson Electric Company can prove that your data is wrong and that the heat will not harm the aquatic community.

Local scientists have advised you that the plant should not pipe hot water directly into the lake. You insist that the company use other methods, such as a cooling pond or cooling towers. The company opposes your position. You think it is because the company is only concerned with its profits. You are sure that the whole lake will be harmed.

You know that the company is doing research to obtain more data about the effects of heat on Serena Lake. They are gathering data at the coal-burning power plant now operating on the lake. You do not think this is a good procedure. You want data

collected from several places around the lake. This will show what thermal pollution could do to the whole lake.

Central City also depends on the lake water for drinking. You are concerned that changes in the lake will make the water unfit for drinking. You urge the SSC not to allow the plant to be built until the company can guarantee that the lake will not be harmed. You are sure a cooling pond or cooling towers will provide the guarantee. You are angry that the state government spends millions of dollars to clean up water pollution, and then permits a power plant to pollute. You insist that individual citizens have the right to prevent pollution.

Central City Industrial Association

The Association represents many of the city's industries. The Central City area has steel, oil, chemical, automobile, and many smaller industries. Your organization strongly supports Wattson Electric's plans for the power plant. It will provide cheap electricity. Industry around Central City is growing. Industry's need for electricity is increasing, too. When industries expand, they create more jobs and prosperity.

There are many growing companies that now wish to move into the area. Several of these are the Midwest Aluminum Company, Comfort Air Conditioners, and the General Glass Company. But they are waiting to see if the new power plant will be built. Without electric energy, they cannot operate.

The Citizens' Committee demands a cooling pond or cooling towers for the new power plant. You agree with the power company that this demand is too strict. It might hurt the economy because cooling methods cost extra money. It might hurt the environment because cooling towers can warm the air and may cause fogging. If industries pay more for electricity, customers will have to pay more for goods. New industries will not move to Central City, and then there may not be enough new jobs for the expanding population. You believe any benefit to the lake environment will not be worth this cost.

Finally, you think the opposition must prove that the environment will be harmed. Otherwise, industry should not be told what to do or how to do it.

Friends of the Environment (FOE)

FOE is a group with thousands of members all over the area. Your members feel it is their duty to protect the environment. You want to leave the environment for the next generation as unspoiled as possible.

Your organization is strongly opposed to building the nuclear power plant on Serena Lake. In fact, you are against having any plant located on the lake. This includes the power plant already

operating there. You believe that people cannot go on adding heat to the environment without damaging it. You are convinced by the data that shows the effect of heat on aquatic communities.

You are certain that the solution to the thermal pollution problem is for people to use less electricity. Then new power plants would not be needed. You also want to see research on the possibility of making electricity from the wind, ocean tides, underground heat, or sunlight.

You think anyone who supports the plant is irresponsible. You say they only care about using the lake to make money. But everything in nature does not exist for people to profit by. You feel that the lake should continue to exist unchanged.

The majority of City Council members

You are residents of Central City. You have lived and worked here all your lives. Recently, most of your fellow council members voted to support the present plans for the power plant. You are excited about the money that will come in from the construction and operation of the plant. The plant will also create many new jobs. The area's economy will get a big boost. Local builders, building suppliers, manufacturers, realtors, and landowners will profit.

The Citizen's Committee is trying to force the company to use a cooling pond or cooling towers. You fear that this will increase the cost of electricity and delay completion of the plant. New businesses might decide to find another location. Old businesses might leave the area. Besides, Serena Lake is already somewhat polluted, as it has been for years. No one has proved that it is all the fault of the existing power plant.

You do not want the quality of the lake water to be affected by the plant. You are sure that the company will try to keep the quality of the water high. You want to give the company a fair chance. You think that any hasty decisions to change the design of the plant would hurt the community. One of your frequent comments to local citizens is, "For once in our history, let's try to get something that pays local taxes and does not just spend tax money."

Minority of City Council members

You are residents of Central City. But most of you have lived and worked here less than ten years. You voted against sending a statement to the SSC in support of the power plant. But you were outnumbered. You want the plant to be built on Serena Lake, but not as it is now planned. You consider it your duty to protect the lake. You have read scientific reports describing what happens to lakes when the water is warmed. This data frightens you.

You accuse Wattson Electric of conducting research to prove that thermal pollution will not harm the lake. Otherwise, why would they want to begin to build the plant before all the data is gathered? Also, if they really wanted reliable data, they would collect data from several places in the lake.

You realize that the nuclear power plant will bring in badly-needed taxes. But there are other costs. The local people enjoy swimming, fishing, and boating on the lake. This cannot be measured in dollars and cents. The tourist business would die. That might have as bad an effect on the economy as the loss of the plant. You think a cooling pond or cooling towers is the answer. The benefits would be worth the additional cost. The air could absorb the thermal pollution better than the water. Fewer organisms would be affected.

You claim that there is a lot of opposition in Central City to the plant. Therefore, you support public hearings like this one. They give the public a chance to fully understand the issue. You insist that Wattson Electric must explain its operation to the public.

The data bank

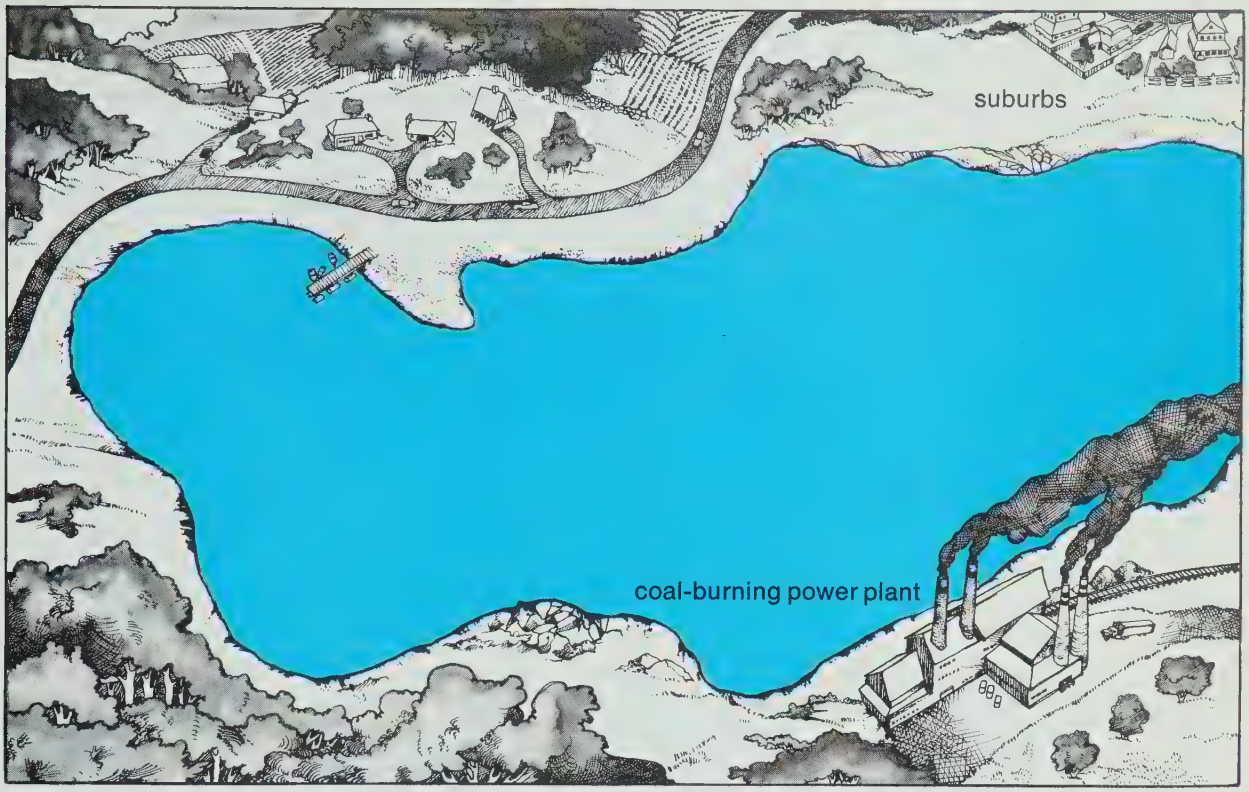
Entry 1, Serena Lake

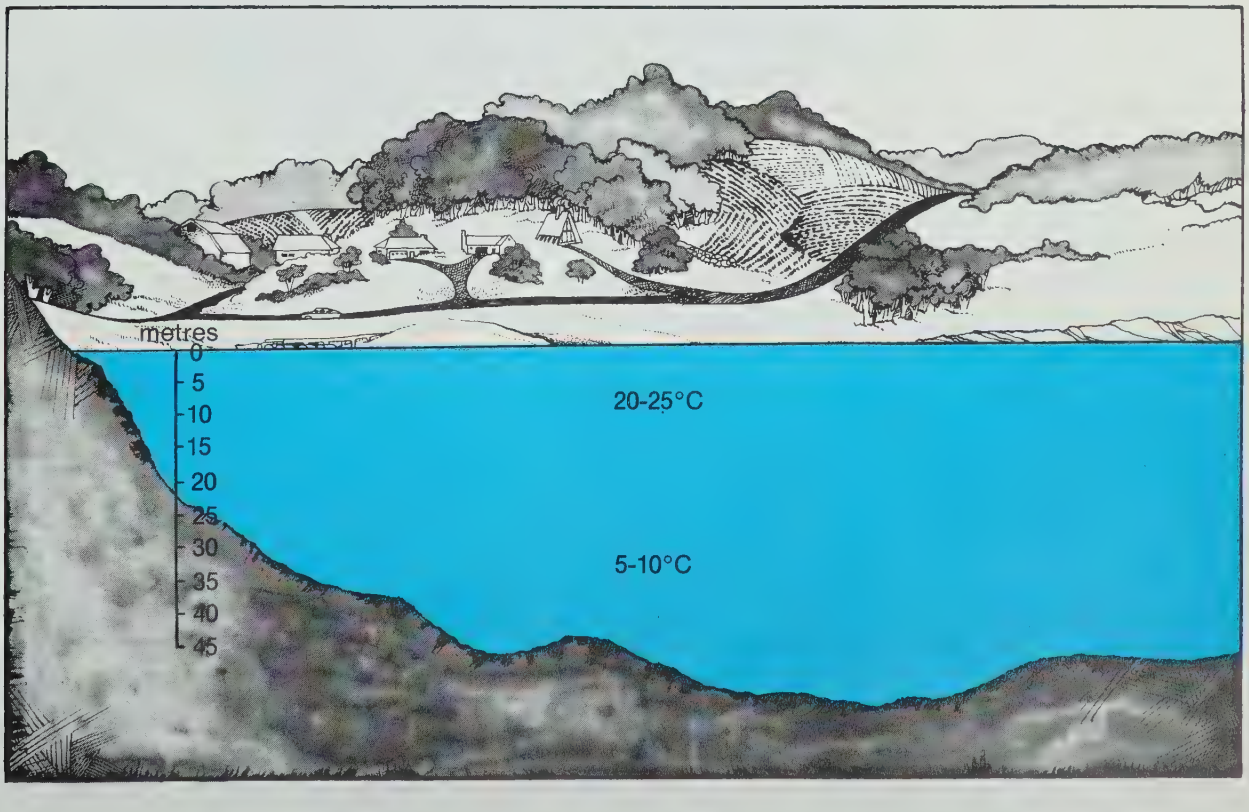
Serena Lake is the smallest lake for which a nuclear power plant has ever been planned. The water hardly moves. The lake borders on an industrial area, but much of the shoreline is still wooded. Water flows out of the lake into a large stream.

From May to November, algae grow in the warm water near the surface. The water temperature in the summer months is about 21°C. Light is available near the surface, along with necessary minerals and gases (oxygen and carbon dioxide). Like most lakes, Serena Lake is gradually filling up.

The area around Serena Lake is being developed for housing, industry, and agriculture. As a result, more soil washes into the lake. Algae is growing so fast that it is making the water cloudy. Recent studies show that Serena Lake is aging unnaturally fast. Twenty years ago, the water was clear down to five or six metres. Today, it is clear to less than three metres. This makes swimming and skin diving more dangerous. Many of the people who live near the lake are worried. Their incomes depend on vacationers who come to the lake to go swimming, boating, and fishing. The cross section of Serena Lake shows how the surface and the bottom temperatures differ.

People use Serena Lake for recreation, city and industrial water needs, and disposal of treated sewage. The estimated values of these uses are from 10 to 15 million dollars a year.


suburbs
coal-burning power plant


metres
0
5
10
15
20
25
30
35
40
45
20-25°C
5-10°C

Wattson Electric already has one small power plant on the lake shore. It uses coal to generate electricity. Waste heat from this plant goes directly into the lake. Waste gases from the smokestacks go into the air. Wattson Electric Company is studying the effects of waste heat from the plant on the lake. So far, the researchers claim that the waste heat does not seem to affect the lake.

The water for this plant is taken from a depth of 15 metres. Water for the nuclear plant will come from 35 metres down. The new plant will use at least four times more cooling water than the existing plant.

Entry 2, The proposed power plant

The Wattson Nuclear Power Plant will be one of the largest power plants in the area. Company officials estimate that it will take five years to build and cost 125 million dollars. The nuclear reactor produces heat. The heat is used to boil water to make steam. The steam spins the turbine to generate electricity. Afterwards the steam is cooled back to water. The steam is cooled by cool lake water that then returns to the lake as warm water. Lake water does not touch the reactor.

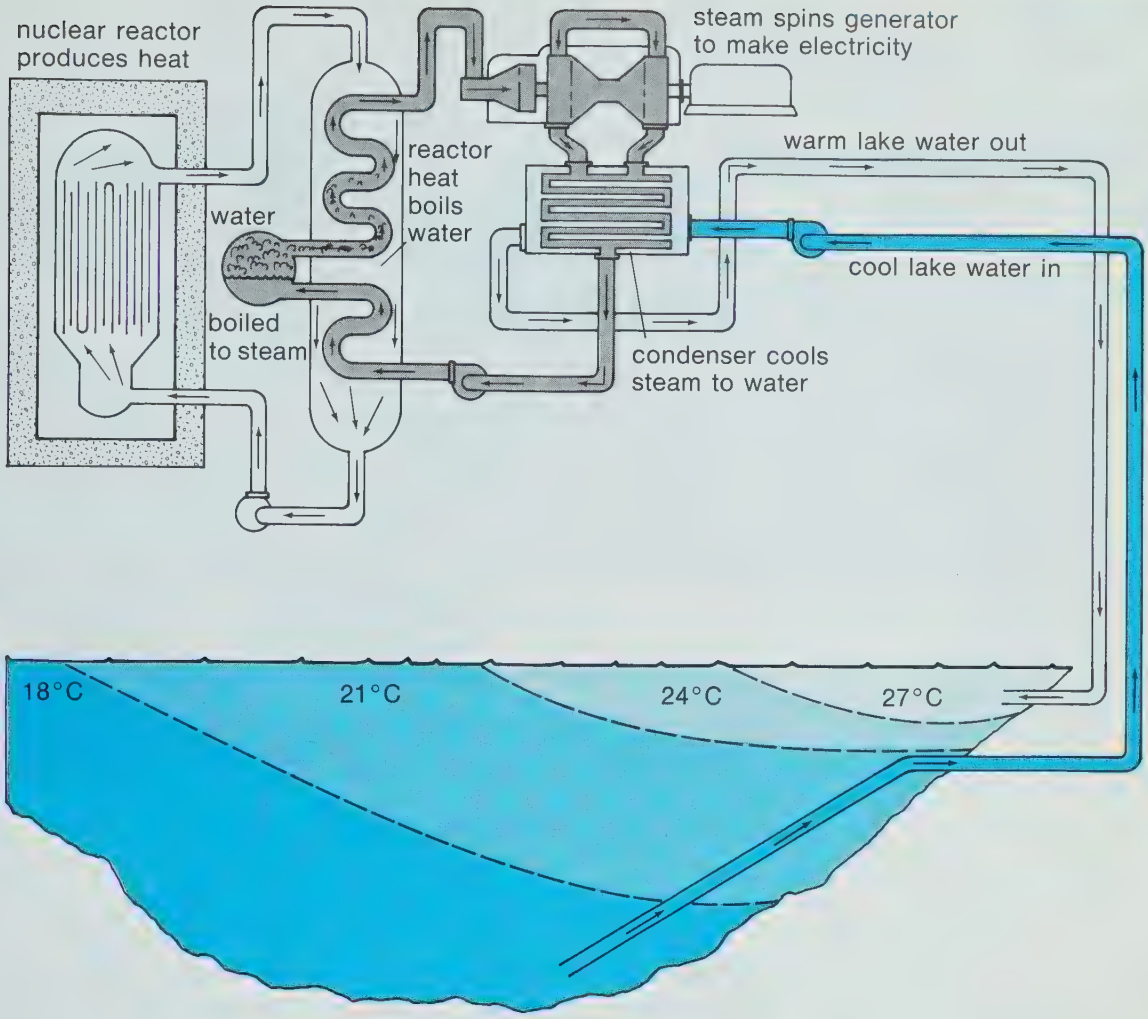
The water for cooling the steam will be taken from 35 metres down in the lake, where the water is as cold as the inside of a refrigerator. When this water comes out of the power plant, it would be 15°C warmer. The heat in the water would spread out in the lake and eventually go into the air. The power company says that the overall temperature of the lake will be raised only 0.5°C. (Is the overall rise in temperature the only figure that matters?)

The water temperature and environmental disturbances are much higher where the water enters the lake.

The nuclear power plant will give off about 50 percent more heat than a plant that uses coal, oil, or gas for fuel. But the nuclear plant will not give off any smoke, dust, or bad smells. It will produce another kind of pollution, though. About once a month the cooling water pipes have to be cleaned. The cleaner is flushed into the lake.

The construction of the plant will provide jobs for about 1000 local workers. These workers will earn at least 25 million dollars. About 15 to 20 million dollars worth of supplies will be purchased locally. All together, the area will receive about 45 million dollars worth of business.

After the plant is built, the power company will pay taxes to the city. These taxes will be spent to build roads and schools and make other improvements. Finally, about 60 skilled workers will be needed to operate the plant.

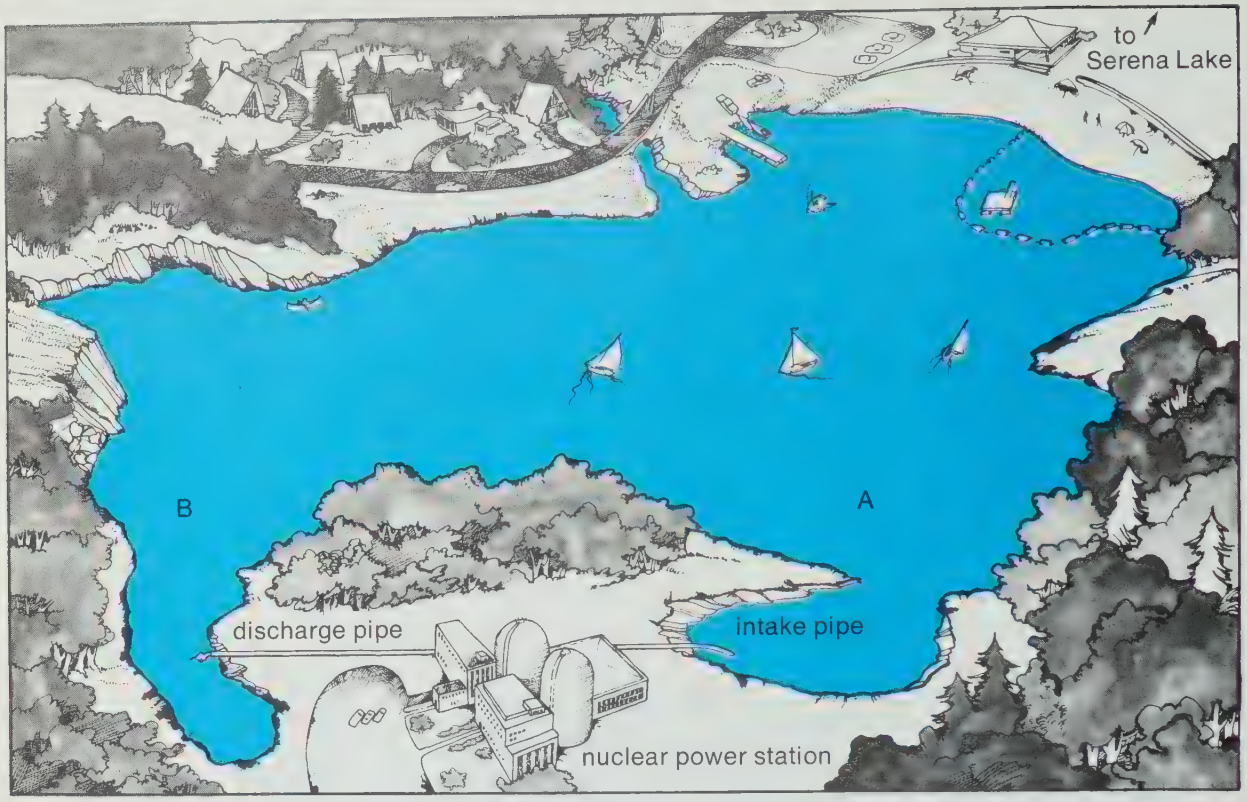


This is how a nuclear power plant works.

Entry 3, Ways to remove heat from power plants

The cheapest way to get rid of waste heat from the power plant is to pump lake water through the cooling system. This method is called the direct-flow method. All the heat goes into the lake.

A cooling pond (page 278) could avoid adding heat to the lake. The pond would be built near the power plant. It would be filled with lake water. The deep end of the pond (A) would contain cool water. This water would be pumped to the plant to cool the steam. The heated water would be released into the shallow end (B). The water would cool off before being used again. The heat would slowly go into the air. Notice that there are some other ways this pond could be used.

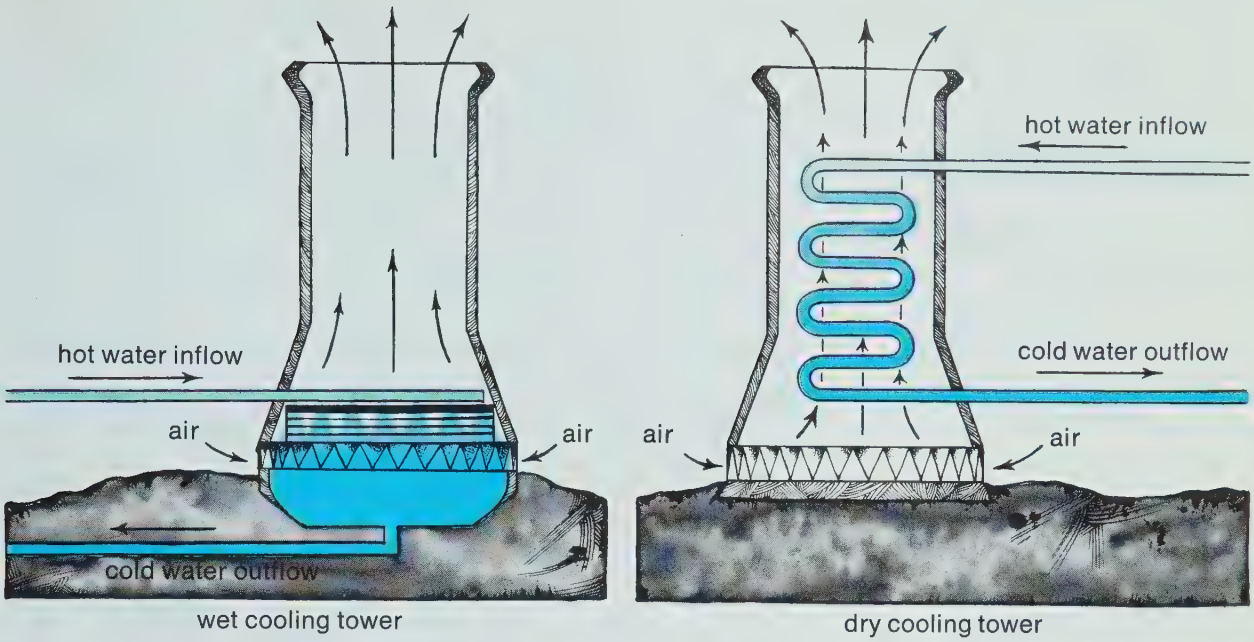


This cooling pond could be built for Serena Lake

A pond for the Wattson Nuclear Power Plant would have to cover about 800 hectares. It would cost about 10 million dollars to buy the land, dig it out, and flood it. Costs are high because the site is hilly. The pond would not be expensive to run, and the water of Serena Lake would not be heated.

Another way to get rid of waste heat is to use cooling towers. In a "wet" cooling tower, hot water from the plant is sprayed over metal plates. Cool air from outside blows up past the plates. Some of the hot water is evaporated by the cool wind. Evaporation cools the remaining water. The cool water can be returned to the plant to be used again. Or it can be piped into the lake. The evaporated water may form a cloud over the area. In cold winters, it could create heavy fogs and icing. In any case, the waste heat goes into the air.

A "dry" cooling tower works like a car radiator. Hot water passes through small metal pipes. The air outside the pipes cools the water inside. There is no evaporation and little danger of fog. The cool water can be returned to the plant to be used again, or emptied into the lake. Again, the heat goes into the air.

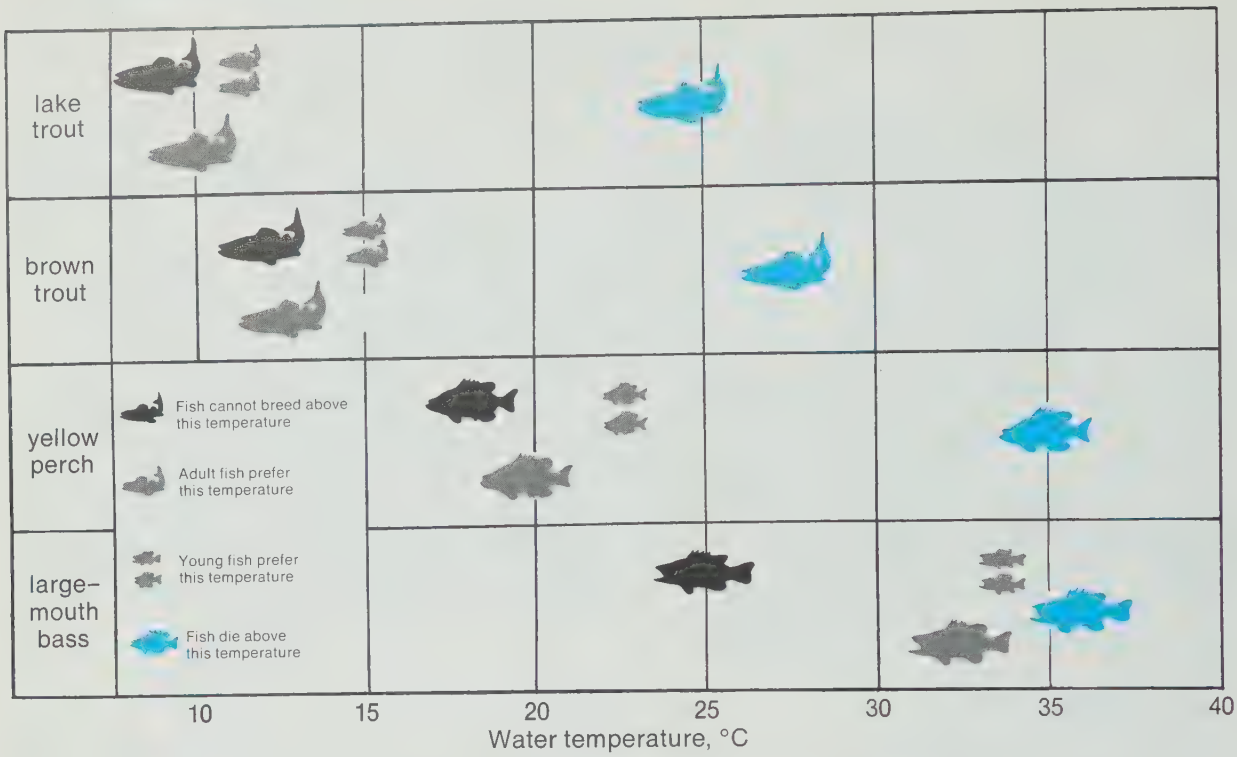


The two "wet" cooling towers in the drawing are each over 100 metres tall. They cool thousands of litres of water a minute. Hot water enters the tower at 30°C. It can be cooled to 10°C by the time it leaves.

Cooling towers would not heat the lake. But they would heat the air instead. Officials of the electric company say that these towers are very expensive. "Wet" towers would cost about 25 million dollars. These costs would increase the price of electricity. The average home owner's electric bill would be at least one dollar more a month. Industrial users of electricity would pay much more than that.

Entry 4, The effect of adding heat to an aquatic community
Increasing water temperature makes aquatic plants and animals grow faster. It speeds up the use of food, and the rate of gas exchange and heartbeat in animals. The organisms grow faster, but they do not grow as large or live as long as in cooler water. Many aquatic animals will not reproduce if the temperature is raised even a few degrees.

The normal growing season for algae and other plants in Serena Lake is from May to November. Warming the lake water may lengthen the growing season. This will speed up the aging process of the lake. However, the exact speed of aging cannot

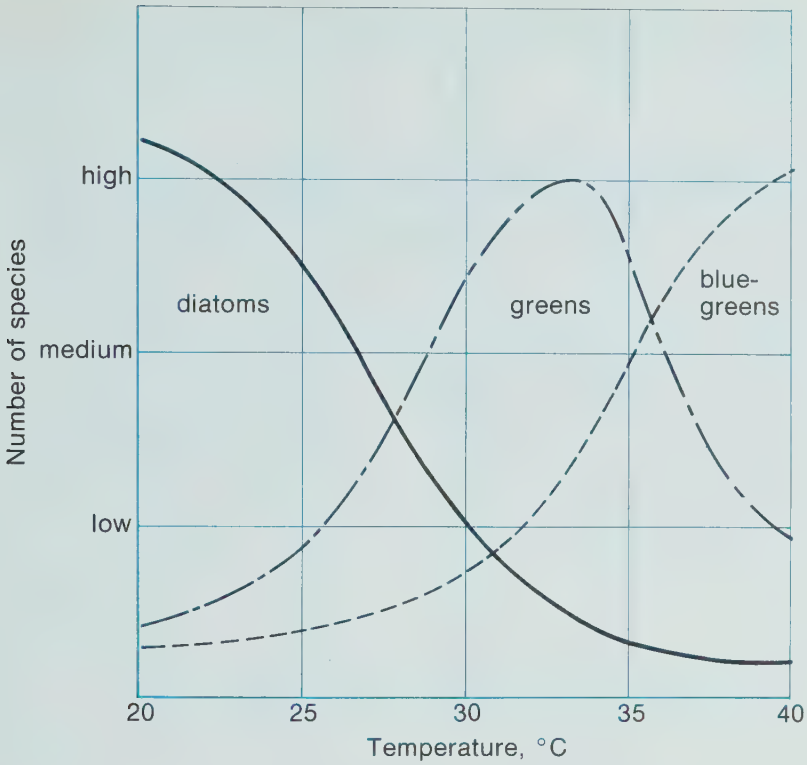


This diagram shows the temperature needs of several kinds of fish.

be predicted. The graph on page 281 shows how water temperature affects algae. Above 20°C, the number of diatoms (DY uh tahms) decreases and the number of blue-green algae increases. Most kinds of green algae need moderately warm water, about 30°C. Some biologists think that blue-green algae are not a good source of food for algae-eating organisms. These organisms seem to grow better when they eat diatoms. Also, many blue-green algae produce an unpleasant smell and taste in water.

Hotter water can hold less oxygen. At higher temperatures, bacteria and fungi will decay dead organisms faster. Decay uses up oxygen. Then there is even less oxygen in the water. Some aquatic organisms need a lot of oxygen. Other organisms grow well with very little.

The best range of temperature is one that keeps the whole aquatic system healthy. Game fish, such as trout, usually need the cooler water near the bottom of the lake or river. Minnows and young fish are found in the warm shallows. Fish, frogs, clams, crayfish, plants—each organism has certain temperature needs. Warming the water may kill off some kinds of young



insects, shrimplike animals, and other plant-eaters. Many fish and frogs that normally eat these smaller organisms starve. Then there are fewer game fish.

Analyzing data

The most important data in this Investigation is not in the book. It is data on how people behave when a decision has to be made. Analyze your own actions in the debate.

1. Did players support their positions by logic and facts rather than by emotions? Does emotion belong in discussions of science and business?
2. Which argument made to the SSC did you find most convincing?
3. Should special-interest groups such as a Citizen's Committee, Industrial Association, or power company be allowed to influence the SSC? What should be the role of special-interest groups?
4. What problems arise in a conflict between desires for prosperity and an unspoiled environment?
5. If you held a new hearing with a new SSC how would you try to change the outcome?

Extend Your View 21-1
Energy wise

Can you explain how energy use is related to the size and lifestyle of a population? The United States is the world's largest energy user, both for total and per person energy use. Many people have suggested that energy use could be lowered in two ways:

1. Use energy more efficiently.
2. Use energy only when necessary.

Choose either set of data. Suggest at least three ways of lowering energy use. How might each of your suggestions change the way people live?

During 1960–1970 there was increased use of electricity in the home. This data from the 1974 Almanac shows specific areas that contributed to this increase.

Table 21-3 *Use of electricity in the home*

Appliance	Percent
space heaters	24
refrigerators	19
air conditioners	18
water heaters	11
clothes dryers	5
stoves	4
miscellaneous	19

"Process steam" is the energy used to produce steam for industrial processing. "Electric drive" is the energy used to run electric motors. "Raw materials" is the energy used to extract raw materials.

Table 21-4 *Energy use in the United States*

Activity	Percent
transportation	25
space heating	18
process steam	16
direct heat	11
electric drive	8
raw materials	6
water heating	4
air conditioning	3
refrigeration	2
cooking	1
other	6

Extend Your View 21-2
A local issue

Can you discuss some of the variables that influence a decision about a new energy source? Your local electric company has decided to build a nuclear power plant in your community. One of the possible sites is right next to your school. The Site Selection Commission has heard both favorable and unfavorable reports from several groups. What are your views? What are the possible arguments for and against this site? Can you suggest any other sites in your community that you think would be better? Give your reasons.



22

The Redwood Controversy®

After you complete this Investigation, you will be able to

1. explain why an environmental issue may be difficult to resolve.

If there were room enough, everyone could have as much space as he wanted. But parts of the earth are already crowded. Within 40 years, the population of the earth may double. Imagine what it will be like to have twice as many people living in your area.

If people had an endless supply of natural resources—energy sources, minerals, and unspoiled landscape—they could use up as much of the resources as they wanted. But the supply is limited. People are already aware of many shortages.

How do people decide who shall own the land and how the land shall be used? How do people decide how to use natural resources? In this Investigation, you will play a game called *The Redwood Controversy*®. You will learn about one way land-use and natural-resource problems are handled. You and your classmates will act out the parts of United States Senators and concerned citizens. The classroom will be turned into the Senate Chamber. You will take part in a Senate hearing to decide whether or not to establish a Redwood National Park.

The best way for you to learn about this game is to play it with a group of adults before going into class. If that is not feasible, talk it through with one or two of your colleagues. The film *The Redwoods* is highly recommended to add realism to the game. It should be shown after the roles are assigned and after the rules have been discussed.



The raw materials for paper products.

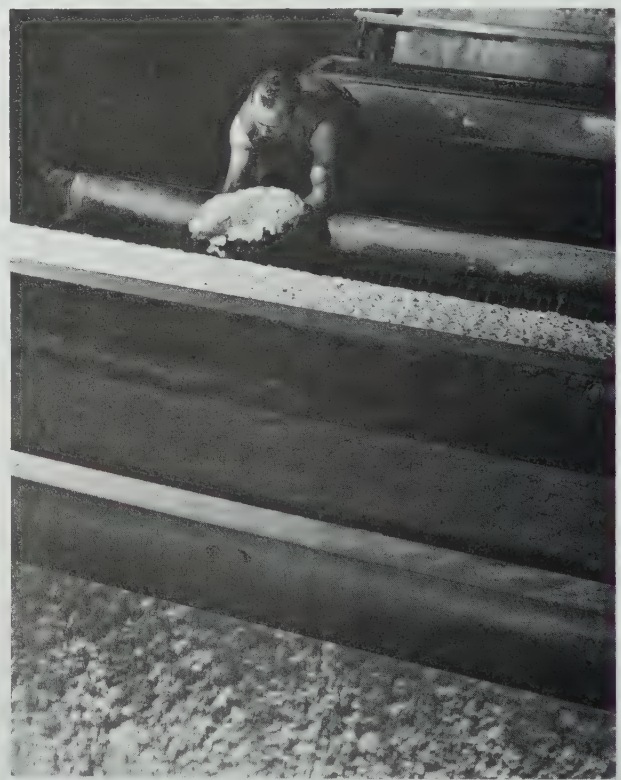


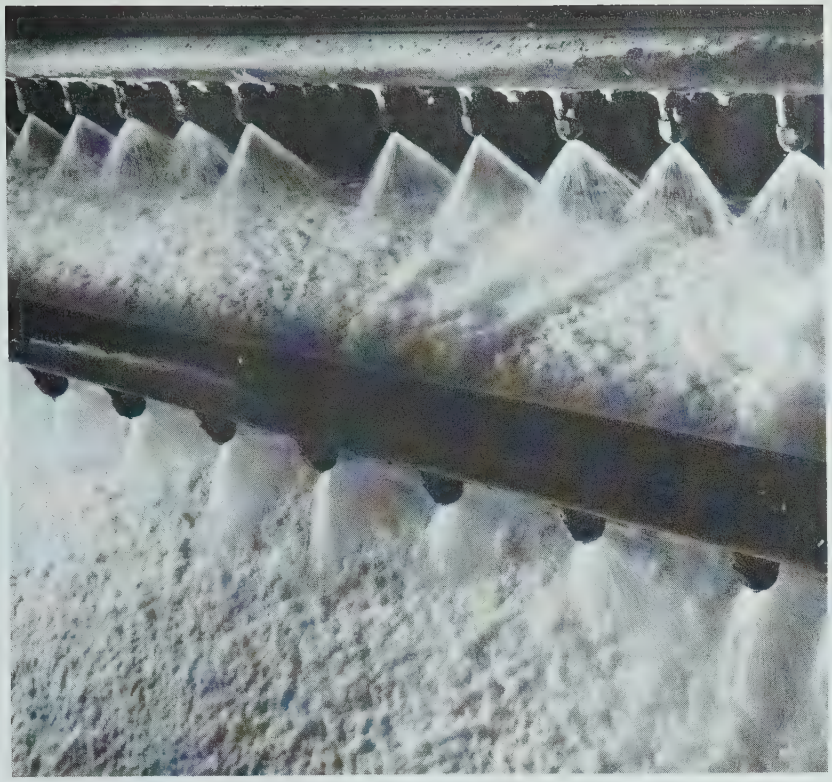
Flatcars of pulpwood being unloaded.

Pulpwood is reduced to chips.



Chemicals turn chips into cereal-like pulp.

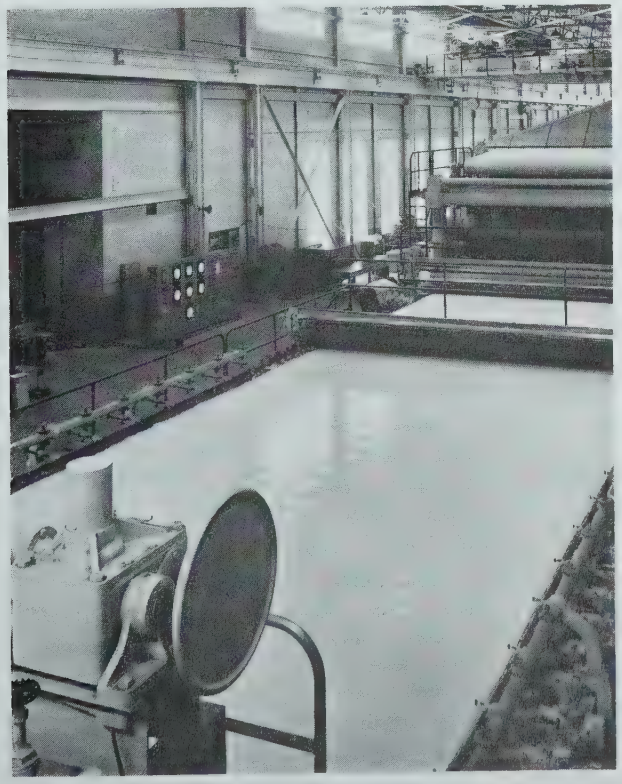




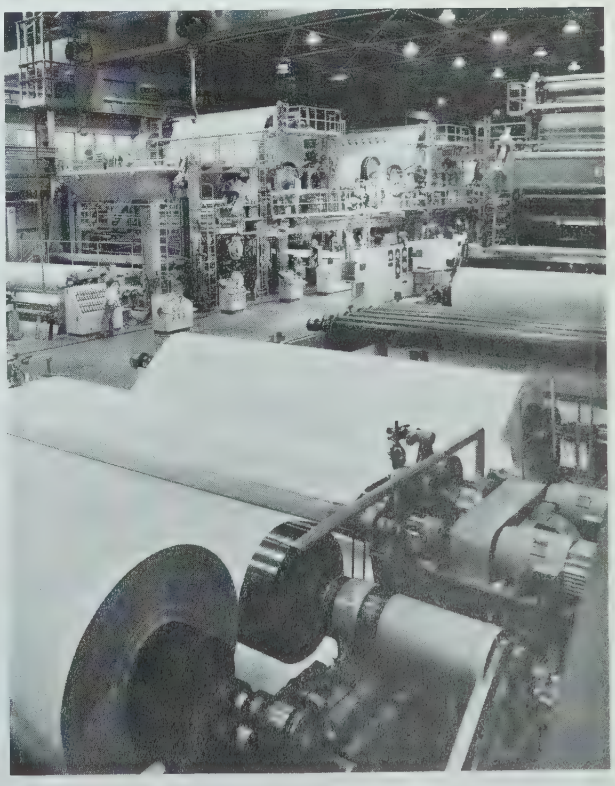
The pulp is washed.

These are some of the steps in the processing of wood into paper.

Machines turn pulp fibers into paper.



A roll of dried paper.



The roles you will play are based on reality, but the actual people you will pretend to be never existed. The evidence you will listen to is real. The kind of debate you will have is similar to those that actually took place. Only this time, you have to decide how to handle the problem.

Investigation 22-1
What will happen to the redwoods?

The United States Senate is about to consider setting up a Redwood National Park. Conservationists have tried to pass such a bill for years. Many newspapers support the proposed park. Lumber companies and people who work in the redwood region strongly oppose any park. Whatever decision is made, there will be many unhappy people. It is the responsibility of each Senator to carefully consider all of the evidence. The Senators should listen to all of the witnesses. Then they must vote for one of the proposals.

The game requires 15 Senators, one of whom you should appoint Senate Leader, and six witnesses. If there are less than 21 students in the class, omit some Senator roles. If more than 21, some students can double up on Senator roles, or observe the game as reporters. It is important to keep the ratio of park supporters and opponents the same.

Proposals

1. Establish a **small national park** by taking over two state parks plus 2300 hectares of private land. Estimated cost to the United States government to purchase the private land is 6 million dollars.
2. Establish a **medium-sized national park** by taking over three state parks plus 7560 hectares of private land. Estimated cost to the United States government to purchase the private land is 20 million dollars.
3. Establish a **large national park** by taking over three state parks plus 28 400 hectares of private land. Estimated cost to purchase land is 75 million dollars.

The Senate can also decide to establish no park at this time.

Roles

Players will be given the roles of Senators and witnesses. Each witness has a special point of view on the park proposals. Each of the Senators gets a different role that shows his personality and how the people he represents feel about the park.

You can either deliberately assign the roles, distribute them randomly, or ask for volunteers.

Rules

1. The Senate Leader calls the hearing to order and tells each witness when to testify. A witness has five minutes to make a presentation. Senators may then ask questions.

Be as unobtrusive as possible. Answer only those questions that directly facilitate play especially those that pertain to rules. Suggest that the Senate Leader call Dr. Smart as the first witness because Dr. Smart sets out the broadest outlines of the proposals

2. After all witnesses have testified, the Senate Leader asks each Senator to introduce himself and state how he thinks he will vote. These "first choices" are recorded by the Senate Leader on the Election Ballot. (Actually, a Senate Committee hears witnesses and reports to the rest of the Senate. The entire Senate then debates the issues and votes. For this game the two steps have been combined.)
3. The Senate Leader declares a 15-minute recess for discussion. One Senator can now try to get other Senators to change their votes.

This session will be characterized by spirited discussions. Exercise minimum restraints. Communication should take precedence over a quiet classroom.

4. The Senate Leader calls the roll, and each Senator casts a vote. These votes are recorded on the Election Ballot. The proposal that receives two-thirds of the votes wins. If no proposal receives enough votes, another discussion session is called. Go on with discussions and voting until one proposal wins.

In reality a simple majority is needed to pass a bill. The two-thirds rule here promotes debate.

5. The Senators take turns spinning the Election Spinner to find out if they have been reelected. The chances for reelection are on each role card. The data on reelection is then posted alongside the votes.

Analyzing data

Discuss the factors that made it difficult to settle *The Redwood Controversy.*® Was the solution based on just the data presented or were personal opinions involved? What compromises, if any, were made? Was it possible to satisfy everyone?

What environmental issues exist in your area? What are the conflicting interests? What solutions have been offered? Who will make the decisions? How will the decisions be made? What kinds of data will be needed?

Other types of land use include the building of highways, taking land for government facilities (such as military installations), and taking land for utilities (such as the Tennessee Valley Authority).

Extend Your View 22-1
Getting oil from Alaska

Can you explain why an environmental issue may be difficult to resolve? By the early 1970's, a worldwide energy crisis had developed. One of the short-term solutions proposed in the United States was getting more oil. There is a large supply of oil in the Prudoe Bay area of northern Alaska. The problem was how to move the oil to the other states. Two ways were proposed.



Members of the Audubon Society clean oil off birds. The birds were stranded on beaches after two tankers collided in San Francisco Bay.



1. The Alaska Pipeline. This involved construction of a pipeline from the oilfield to the seacoast town of Valdez, Alaska. From Valdez, the oil would be shipped in supertankers to refineries at Cherry Point, Washington. One disadvantage of this route is that the pipeline would cross an earthquake zone.
2. The Canadian Pipeline. This would be a pipeline from the oilfield across Canada to refineries in midwestern United States. This pipeline would be much longer and take more time to build. But it would not cross an earthquake zone. Also, the land route would lower the risk of enormous oil spills. These spills are more common when oil is shipped by sea.

What further data would you need to decide between these two proposed routes? What difficulties might there be in solving this problem?



23

What can we do about pests?

After you complete this Investigation, you will be able to

1. discuss how the classification of an organism as a pest depends on one's viewpoint.
2. choose ways of controlling pests that do the least harm to the environment.

Pests are living things that can cause harm or discomfort. The harm can be real or imagined. A mosquito is a pest when it feeds on us. A mosquito bite may only cause us to itch and scratch. But some kinds of mosquito also carry diseases such as malaria and yellow fever. Flies and mosquitoes can be considered "natural" pests. That is, they bother us in any environment. The tent caterpillars shown in the photograph are also natural pests. They can destroy the trees in which they live.

In contrast, people often call dandelions pests because the dandelions grow in a part of the environment someone wants to change into a lawn. In a more natural environment dandelions are just wildflowers. When people decide that the original inhabitants of a place, either plants or animals, are undesirable, they "create" pests. How many organisms are called pests because they interfere with people's plans for the environment? Are people ever pests?

Investigation 23-1
Controlling pests

Ever since people started farming large areas of the earth's surface, their main competition for the crops has been rodents and insects. In a field or in the woods, these animals must compete with many different organisms for food and space. They have natural enemies that help to keep their populations in balance. But farming destroys many organisms and their homes and food supplies. Often, the few kinds of organism that remain develop large populations. They may begin to feed on the planted crops. Then people go to war against these "created" pests.

Gathering data

You will share the study of four reports on pests with your classmates. Your teacher will help you decide how to divide up the work. The reports are about some problems that result when people make serious changes in their environment. Do these kinds of problem exist in your community or in your area? You could call your local conservation officer, Audubon Society, Sierra Club, or newspaper to find out. Or you might start looking for information in your library.

Report 1

Help students keep in mind that the problem involves the total environment, not just the negative aspects of toxic pesticides. Long-range solution of pollution problems must come from changes in people's attitudes. The problem is sociological as well as technical in nature. Hopefully, students will become consumers who will direct technology rather than blindly embracing each new product.

The weapons used most often in the war against insects are chemical poisons. They are called **pesticides.** Farmers have covered millions of hectares with pesticides to try to protect their crops. A pesticide is sprayed over an area to control what is called the "target insect." These pesticides usually do decrease the population of the target insect. But it is often impossible to predict all the effects of spraying. Here are some examples of unexpected effects of spraying pesticides.

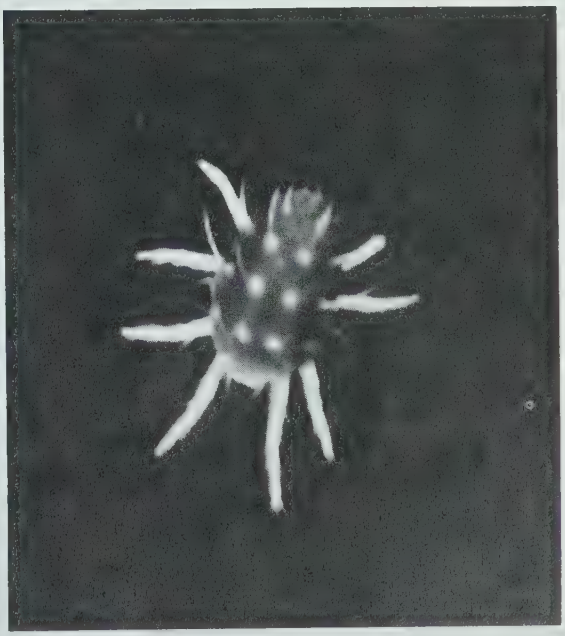
In North Africa, cotton growers sprayed their fields with DDT to control insects that feed on the leaves of cotton plants. The spraying was successful; so the growers continued the program. Then something unexpected happened. The bollworm, a more destructive insect pest, began to multiply. Instead of attacking the leaves, the bollworm attacks the place where the cotton fibers are produced. Apparently the DDT killed the natural enemies of the bollworm, but not the bollworm itself. The unsprayed cotton suffered less damage than sprayed plants.



cropduster



bollworm



mite

Depending on your viewpoint, each of the organisms in these photographs could be considered a pest.

Though some of the leaf-eating insects had been eliminated, more cotton was destroyed.

In Louisiana the fire ant is considered a nuisance. Its sting is painful. In addition, fire ants build large nests or mounds that make it hard to use farm machines. But they are not a serious pest to the crops. The state decided to kill the fire ants with the pesticide heptachlor (HEHP tuh klohr). The heptachlor also killed the natural enemies of the sugarcane borer. With fewer enemies, the sugarcane borer multiplied. The damage to sugarcane crops in Louisiana was so great that farmers sued the state for careless use of poisons.

The spruce budworm attacks evergreen trees. The young spruce budworm tunnels into needles and buds. Forests in southeastern Oregon and northern Maine have been badly damaged. To control the spruce budworm, United States Forest Service planes sprayed 354 000 hectares of forest-land with DDT. The program looked like a success. Most of the budworms were destroyed. But the next summer the trees were dropping their needles. Forests were turning brown. Damage was worse than before the spraying. A closer look revealed this data.

1. The red spider mite, which also preys on evergreen trees, was not killed by the DDT.
2. Spraying disturbed the spider-mite colonies. The mites scattered, looking for places where they would not be disturbed.
3. Animals such as the ladybug beetle, which eat spider mites, were destroyed.
4. Finally, the spider mites, with no enemies to control them, were doing great damage to the trees.

What went wrong in these three cases of pesticide use?

Report 2

Until this century people were unable to fight diseases such as malaria or yellow fever. As recently as 1945, there were over 60 000 cases of malaria a year in the United States. Then people began using the insecticide DDT to kill the mosquitoes that carry malaria. The number of new malaria cases dropped rapidly. By 1950 there were only 2000 cases a year. DDT has been helpful in fighting other diseases carried by insects, too. Some people estimate that DDT has saved 25 million lives.

The use of DDT on farmlands has helped increase food production. During the 1960's, people used DDT to control

army worms, blister beetles, corn borers, and many other damaging insects.

If DDT has been so helpful, why is its use forbidden in many places, including the United States? It is now known that DDT and similar pesticides poison many other kinds of animals besides the "target pest." These pesticides are spread through the environment by wind and water. Pesticides, such as DDT and dieldrin, that stay poisonous for many years are often called "hard pesticides." It is estimated that over half a billion kilograms of these chemicals are now in the earth's water, air, and soil.

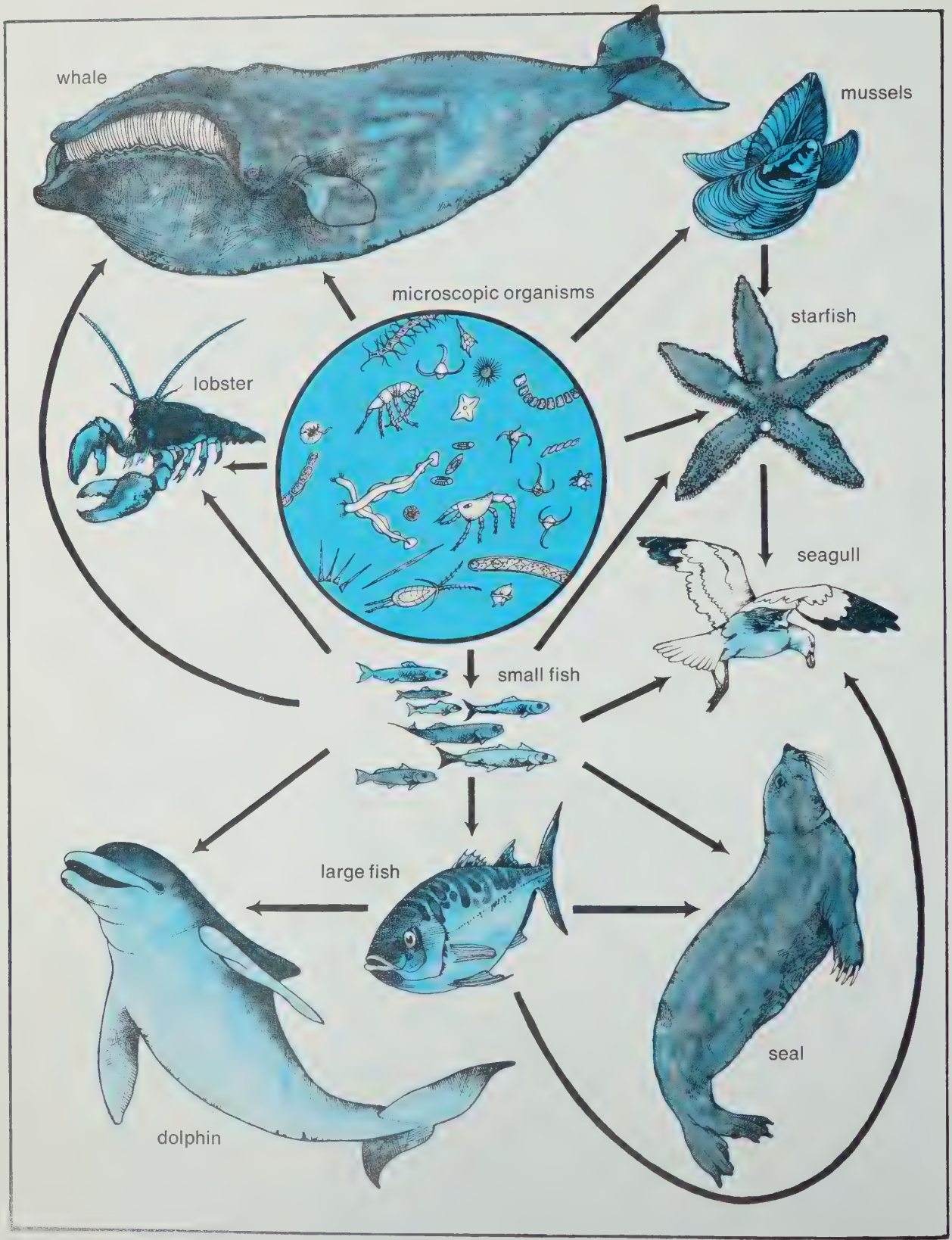
Seals live in the ocean where no hard pesticides have been used. Part of the food web for seals is on page 298. Notice that seals eat fish. The fish eat smaller organisms in the ocean. In one study, scientists examined seals in the ocean between Scotland and Canada. High concentrations of DDT and dieldrin were found in their flesh. Where do you think these poisons came from?

Clear Lake, in Northern California, is a popular vacation spot near San Francisco. It is also the living and breeding area for grebes. Grebes are fish-eating ducks. At one time, there were about 1000 pairs of grebes around Clear Lake. They build floating nests on the edges of lakes. In the winter of 1954, the grebes of Clear Lake began to die. By 1969, only about 30 pairs were left. They made nests, but no young grebes were seen.

An investigation showed that resort owners and tourists at Clear Lake had been bothered by swarms of gnats (nats). Gnats



This grebe is on its floating nest.


whale
mussels
microscopic organisms
starfish
lobster
seagull
small fish
large fish
seal
dolphin

are tiny biting insects that breed in the lake. People wanted to kill the gnats to make the lake more pleasant for themselves. They decided to use a new chemical, DDD.

Before the spraying, the lake was carefully surveyed. The total amount of water in it was calculated. There was evidence that one part of DDD to every 70 million parts of lake water would kill the gnats, but not the fish. The lake was first sprayed with this amount of DDD in 1949.

At first the gnats were controlled. In a few years, however, swarms of gnats returned. Clear Lake was sprayed several more times over the next eight years. The amount of DDD was increased to one part of DDD per 50 million parts of lake water. But this amount of DDD was supposedly low enough not to harm the fish.

Table 23-1 shows the amount of DDD found in the plants and animals of Clear Lake. The food chain in Clear Lake was now a poison chain. The poison had moved from microscopic organisms to fish to grebes. The lake had been sprayed with low levels of DDD. Is there an absolutely safe amount of hard pesticides that can be added to any environment?

Table 23-1 *Amount of DDD in Clear Lake*

Location	Amount of DDD (parts per million)
water	0.02
microscopic plants and animals	5
plant-eating fish	40–300
fish-eating fish	500–1500
grebes and gulls	over 2000

Japanese beetles were first seen in the United States in 1916. They probably entered the United States on plants brought from other countries. Japanese beetles damage crops and lawns. The young beetles, called grubs, live underground. They eat roots. The adult beetles eat the leaves of many kinds of plants and trees.

Two different methods to control the Japanese beetle have been tried. In 1954 the United States Department of Agriculture and the Illinois Agriculture Department started to use dieldrin. By 1961, 52 460 hectares near Sheldon, Illinois had been sprayed. Dieldrin soaked into the soil and killed many beetle grubs. It also killed other insects and earthworms.

By 1961, entire bird populations around Sheldon, including starlings, brown thrashers, meadowlarks, grackles, and pheasants, were almost wiped out. Robins were rare. Only a few of

The main effect of DDT on bird eggs is to make the shells extremely fragile. Many times, the female bird will break the eggs by just sitting on them. The breaking of the shell results in the embryo's death.

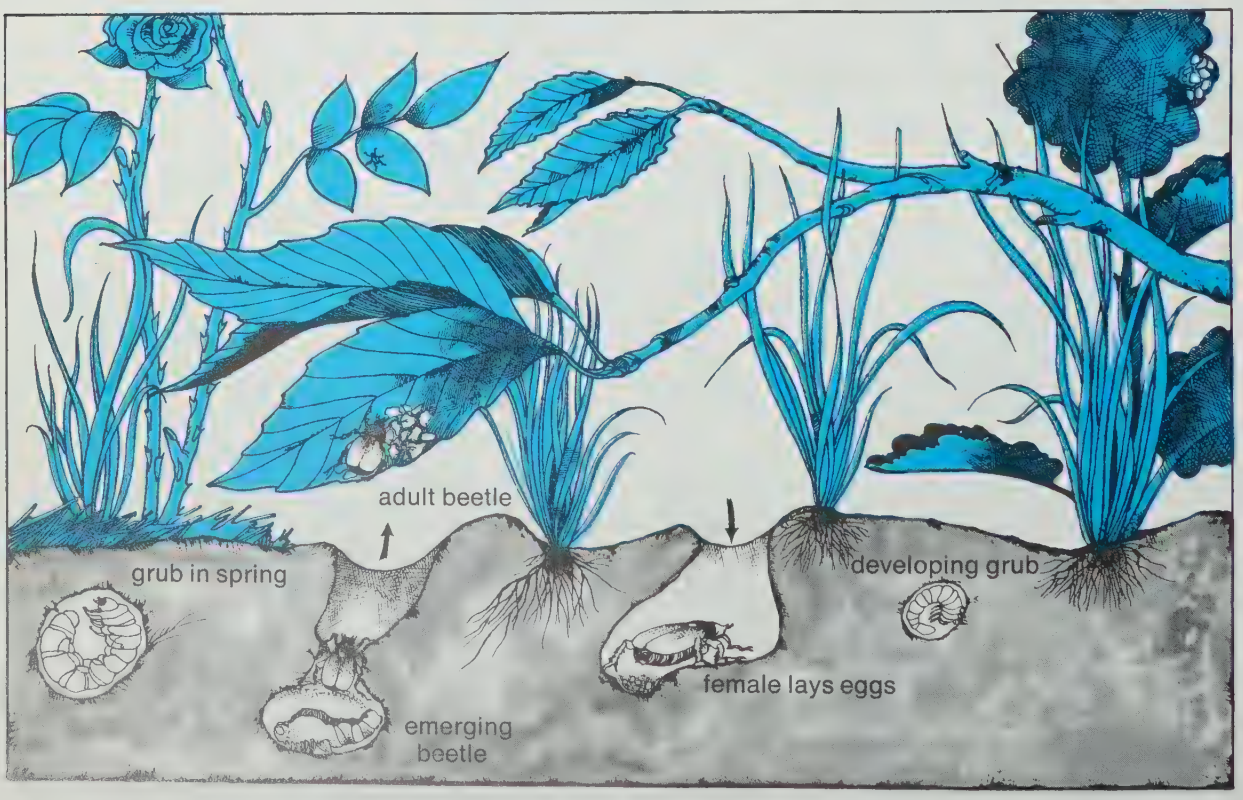
the birds that survived produced eggs. And there were no young birds in the nests the next summer.

In addition, large numbers of dead ground squirrels, rabbits, and muskrats were found in the treated areas. The town of Sheldon lost its whole fox squirrel population. Ninety percent of all the farm cats died during the first season of spraying. Although many other animals were dying, the Japanese beetle still continued to spread.

In another attempt to control the Japanese beetle, some people in the eastern United States decided to use a kind of bacteria that causes disease in the beetles. This kind of bacteria does not attack other kinds of insects, earthworms, mammals, or plants. The Japanese beetle grub takes in these bacteria with its food. The bacteria grow rapidly in the grub's body. Because the beetle's body turns white, the disease has been called "milky spore disease."

Between 1939 and 1953, the bacteria were added to the soil of 14 states. By 1945, milky spore disease was found in the beetle populations of Maryland, Delaware, New Jersey, New York, and Connecticut. The use of milky spore disease bacteria

Follow the life cycle of the Japanese beetle.





A Japanese beetle larva is normally dark-colored (left). A larva infected with milky spore disease (right) is much lighter in color.

was more expensive than spraying and did not show immediate results. What is your opinion? Which treatment would you prefer in your area?

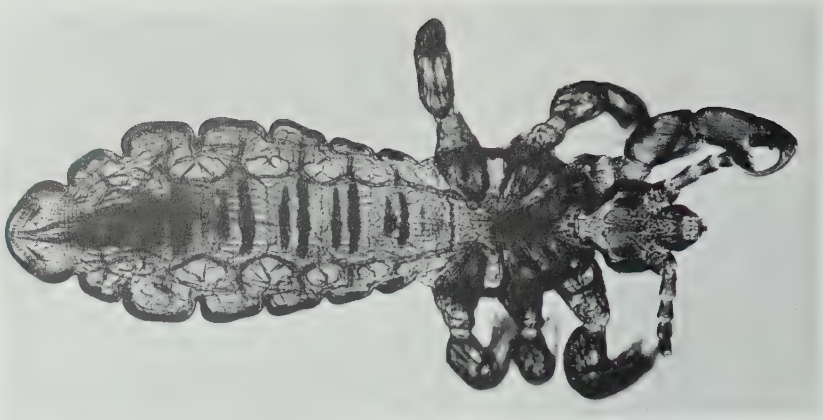
Look at the cans of insect- and weed-killers in your home or stores. What chemicals do they contain? Look for DDD, DDT, DDE, aldrin, endrin, methachlor, lindane, chlordane, dieldrin, heptachlor, or epoxide on the label. These are all hard pesticides. Their use may contribute to the amount of long-lasting, poisonous chemicals in the environment.

Some of these chemicals have already been taken off the market in the United States.

Many of these chemicals are known to be very poisonous in large amounts. Many of the foods we eat contain at least small amounts of pesticides. No one knows the damage that might result from eating small amounts over a long period of time.

Report 3

Farmers now have cows that give more milk than cows did 50 years ago. Today's chickens lay more eggs and racehorses keep breaking speed records. These improvements in organisms have



The body louse is an insect that spreads typhus.

been produced by **selective breeding.** In selective breeding only the organisms with the most desirable properties are mated. After many generations of selective breeding, an organism may be very different from its ancestors. Or it may just be superior in a few specific properties.

Without meaning to, people have been breeding superior pests. In 1943 in Italy, a program was started to control diseases that were spread by insects. People were dusted with DDT powder to kill the body lice that spread a serious illness called typhus. At the same time, DDT was sprayed in houses to control mosquitoes that spread malaria and houseflies. In both cases there were some insects that had an inborn ability to resist the pesticides. They survived and passed their resistance to their offspring. Each time the treatments were repeated, fewer and fewer insects died.

In 1948, a new chemical, chlordane, was added to the DDT spray. The new spray worked well for two years. However, by 1950, resistant flies appeared that were not killed by chlordane. Within a year all houseflies and mosquitoes seemed to be resistant. The following year, six new chemicals were tried. None worked for very long.

At the end of the treatment period the fly population was just as large as before. But the flies were now resistant to the eight chemicals used. The environment was also loaded with dangerous pesticides.

Insects that live on farm crops are also showing resistance to chemical poisoning. In 1960, 65 kinds of insect were known to be resistant. Now there are over 200. Among these are the codling moth, whose larvae make apples "wormy," and the Colorado potato beetle. There are now six kinds of resistant insect that feed on cotton.



Colorado potato beetle

Chemical treatment of crops to prevent plant disease and crop destruction is sometimes effective for a short while. But if resistant strains of insect appear, should more poisonous chemicals be used? There is the problem of the added cost of more pesticides, and the chance that resistant insects will appear again. In addition, a lot of poisonous chemicals will have been added to the environment. Spraying programs may spread poison on the land, and not even reduce insect damage over the long run.

Report 4

Some scientists are trying to control insect pests without harming other living things. They either try to trick the pests or use organisms that prey on the pests. In some insects, the female releases a chemical during the mating season. The odor of this chemical attracts the male. You may remember that many moths do this. Some flies do, too. Scientists have made chemicals that will attract a number of kinds of insect including gypsy moths and fruit flies.

One way to use the chemical is to combine it with a poison. When the "poison-perfume" combination is put on pieces of fiberboard, it attracts only the male target insects. This way the poison does not become widespread. This method was tried out in 1960 on islands near Japan. One year later, only one percent of the fruit fly population remained.

These reports are of isolated and specific cases. Students should not get the idea that these methods are universally successful. However, it is the specificity of biological techniques that makes them valuable and usually less harmful to the environment than hard pesticides.

Sometimes pieces of fiberboard or cork are coated with a sticky substance instead of the pesticide. The males, attracted by the female odor, are trapped on the fiberboard.







The lady beetle (top left), the dragonfly (top right), and the praying mantis (bottom) all feed on other insects that people consider pests.

In another method, large numbers of a pest are raised in a laboratory. Then they are given heavy doses of radiation. The radiation makes the males **sterile,** or unable to produce offspring. Swarms of these sterile males are then taken to where the wild pest lives. The sterile males from the laboratory mate with the wild females, which mate only once. Because the males are sterile, the eggs do not develop.

For this technique to work, more sterile males than fertile ones must be produced and dispersed. One insectory at Mission, Texas produces 190 million sterile screwworms per week. These are boxed in groups of 2000 and air-dropped near the border of the United States and Mexico. This technique effectively halts the northward movement of the screwworm.

Releasing large numbers of sterile males eliminated the screwworm, a serious cattle pest in Florida. The female screwworm lays her eggs in cuts and scratches on livestock. The eggs hatch into maggots that feed on the host animal. Sterile males are also being tried in California to control a kind of bollworm that feeds on cotton plants.

Some bacteria produce poisonous substances. One kind produces a poison that kills caterpillars of the flour moth and cabbage butterfly, and the root borer of bananas. The bacteria are spread over plants. When the caterpillars eat the treated plants, they die. The difference between this poison and other pesticides is that the bacterial poison kills only certain insects. It is not harmful to any other organisms.

In California, fields of alfalfa are now being sprayed with a virus. The virus kills alfalfa caterpillars, saves the alfalfa, and does not harm the livestock that are fed alfalfa. In Canadian forests, scientists are attempting to control the pine sawfly, a pest of lumber trees. They are spraying the forests with a virus that kills sawflies. The virus will become a permanent feature of the forests. Therefore, it should control the sawfly population over a long period of time. There is no evidence that these viruses can cause disease in other animals.

Just as some insects are resistant to pesticides, some insects are resistant to viruses and bacteria.

The use of predators to control harmful insects also shows great promise. Canada is trying this method to control sawflies. The shrew, a small mouse-like animal, was recently brought



short-tail shrew



This photograph shows scale insects.

to Newfoundland, Canada. The sawfly lives part of its life in the soil beneath the trees. Here it is often eaten by shrews. One shrew can eat as many as 800 sawflies each day. It is not yet known if the shrews will control the sawfly, but early results seem promising.

In 1880 a scale insect threatened to wipe out the citrus trees in California. The insects feed on the sap of the trees. A small beetle that ate nothing but scale insects was imported. It has kept the scale insects under control. Recently, chemical sprays used to control other insects have killed off this desirable beetle. The scale insects are less affected by the sprays. They are again threatening the citrus groves.

Why do you think that these methods seem to work? Do you think these methods solve all the problems of controlling pests?

Sometimes, biological control methods have drawbacks. Consider the case of the backswimmer. This insect can be used as a predator against mosquitoes that have developed a high tolerance to insecticides. However, if the backswimmer ends up in ponds or swimming pools it can inflict painful bites on swimmers.

Analyzing data

1. What do you think should be done before any large spraying program is started?
2. Should people try to stop the spread of hard pesticides in the environment? Would you be willing to tolerate pests to do this? Insect-damaged food is usually thrown away. This raises the price of the food that remains. Would you be willing to buy food that had some insect damage?
3. When are pesticides useful? When should they be avoided? Who should make these decisions?
4. What are the alternatives to living with insect pests or using pesticides?
5. Can you think of any ways to control pests in your home or yard without using poisonous chemicals?

Extend Your View 23-1
Point of view

Can you discuss how the classification of an organism as a pest depends on one's viewpoint? Discuss with your classmates these five examples of possible pests. Do all of you agree that these are pests? Explain your answers.

1. Some people make wine from dandelions. Are dandelions pests to these people?
2. A farmer plants soybeans in the field where he grew corn the year before. He now finds much corn growing among his soybeans. Is corn a pest to the farmer? to the soybeans?
3. Insects often get smashed on the windshields of moving cars. Are people who drive, pests to the insects?
4. Children like to catch fireflies and keep them in bottles. Are children pests to the fireflies?
5. Rabbits eat carrots and corn that grow in gardens. Are rabbits pests to these plants? to the gardener? Some people enjoy hunting rabbits. Are hunters pests to rabbits? Are rabbits pests to the hunters?

Extend Your View 23-2
Mosquitoes as pests

Can you choose ways of controlling pests that do the least harm to the environment? A city in Ohio was invaded by huge numbers of mosquitoes. Even children waiting for school buses were bitten. This community decided that the mosquitoes were coming from a nearby wildlife preserve. The preserve was quite swampy.

A citizen's committee demanded that the swamp be sprayed with pesticides to protect the children. The people who managed the wildlife preserve and a group of people concerned about the quality of the environment argued against the use of hard pesticides.

Suppose you were a member of the city council. Your vote would help decide how this pest problem could be solved. How would you react to the proposal to spray the swamp? What other information would you want before voting?


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Controlling pollution

After you complete this Investigation, you will be able to

1. modify *The Pollution Game* to make it more realistic.

Paper-pulp mills sometimes give off a foul odor. A government official was once asked what was going to be done about this terrible air pollution. He replied, "What pollution? All I smell is money."

Many pollution problems are worldwide. Decisions in one part of the world may affect other regions. For example, a decision by oil-producing countries to raise the price of oil could result in coal being used instead. Burning coal may pollute the air more than burning oil. Or the increase in the price of oil may encourage the development of solar energy.

Investigation 24-1
The Pollution Game

In this Investigation, you will play *The Pollution Game*. You will see how the actions of individuals and organizations affect efforts to control pollution in a community.

Before letting your class play the game, read over the game rules. You might even play the game beforehand with a few friends to familiarize yourself with how it works.



Pollution is a worldwide problem. It may take cooperation among countries to resolve the problem.

(top) helicopters flying over Stonehenge in England, (right) sewage in Tuscany empties into the River Arno, (opposite page) industrial pollution in the Mediterranean area





Display the game components as you discuss their functions. Explain just enough of the rules to get the teams started. The game is designed to be played simultaneously by competing teams of players, although it will work if there is only one set and one team of players.

How to play

Your teacher will show you the different parts of the game and then go over the rules with you. The game can last either one or two class periods. The amount of time should be agreed on before play begins.

The game can be played by four players, if one player also acts as banker. If a person is both player and banker, he must keep the bank money separate. A tie vote defeats a proposal.

1. Each team gets a copy of *The Pollution Game.* A team consists of four players and a banker. The banker is a cashier, who does not vote or own property or a car.
2. Team players roll the dice to determine the ownership of property and the order of play. The highest number picks one set of properties and makes the first move. (All the properties in a set are the same color.) The next highest number picks another set of properties, and so on. The lowest number becomes the banker.
3. When the game begins, each player gets $3500 and two Election Cards from the banker. The players receive $500 each time they pass "Start." To advance around the board, a player throws the dice and moves clockwise the number of spaces shown on the dice.
4. Each player collects rent or fees from the other players that land on his property. The rates are given on the board. Some fees change as the Air and Water Pollution Indexes change.

Students will likely be unhappy about the rate of environmental deterioration and their inability to prevent it. This is a deliberate simulation of our current dilemma.

5. To begin, set the Air Pollution Index and Water Pollution Index at 10. As some businesses make money during the game, they pollute the air or water or both. Players' cars also cause air pollution. The changes in pollution levels are noted by the players on the Pollution Indexes. If either Index reaches the Lethal Limit, all members of the team lose. (Lethal means deadly.) An Index does not change if a player lands on his own property.
6. When a player passes Speedy Auto Company, he must get his car tuned up and his pollution control device checked. He can choose from three kinds of tune-ups. The best tune-up costs the most, but prevents the most pollution.
7. To get money to stay in the game, a player may sell some of his properties to other players or to the bank. The buyer and seller have to agree on a price. Any player who loses all of his properties is out of the game. If a property is owned by the bank, no rents or fees are collected on it. Players can keep a written record of any sales of property.
8. When a player lands on "Take a Chance," he must take the top card and read the instructions out loud. All players must follow the instructions before the next player takes a turn. If all of the cards have been used once, shuffle them and

begin again with the top card. Unless the card says otherwise, "Take a Chance" fees go to the bank.

9. If a player wants to reduce the pollution, he can call for an election when he passes "Start." He must give one of his Election Cards to the banker. Since each player has two Election Cards, the team has only eight chances to change the rules.

During an election, the players select the proposal they would like to adopt. A majority vote is necessary to pass a proposal. Individual players are free to vote as they want.

10. At the end of the playing time, the team that has the lowest Air and Water Pollution Indexes wins. The individual winner in the class is the player who has the most money. But an individual cannot win if his team pollutes to the Lethal Limit.

You might begin a discussion with questions like these.

1. What ways do people have to make other people stop polluting?
2. Why are some sources of pollution difficult to control?
3. What can a citizen do to cut down on pollution?

Election Ballot

Proposal 1
Charge all properties shown on the Mill City map for city pollution control. Players must add up the current rents and fees for these properties and pay half the amount to the bank. This will lower the Air and Water Pollution Indexes by 15 points. (This proposal can be voted more than once.)

Proposal 2
Each player invests $200 for research on ways to control air and water pollution. This investment in research may pay off in the future. Watch the "Take a Chance" cards. (This proposal can be voted more than once.)

Proposal 3
Pass a Mill City law against adding poisonous wastes to the Little Muddy River. Valley Steel and Gordon Paper Company must each pay to the bank $800 to install new equipment. Each company will then pollute the water at the lower rate of 5 points (it was 10) for each $500 earned.

Proposal 4
Pass a law to make Atomic Electric Company cool the water it discharges into Clear Lake. It will cost Atomic Electric $1200. The company's pollution rate will then go down to 2 points (it was 4). But customers will have to pay $600 now, instead of $400.



Proposal 5
Build a new waste-disposal plant for Mill City. The new plant would dispose of all garbage and trash without producing a lot of smoke or gases to pollute the air. Each player must contribute $100. The Air Pollution Index will go down 15 points.

Proposal 6
Pass a Mill City law to limit the amount of smoke and gases coming from chimneys. Valley Steel, Gordon Paper, and Progressive Chemical Company will have to pay the bank $800 each to install air filters on their chimneys. Each company will then pollute the air at the lower rate of 5 points (it was 10) for each $500 earned.

Proposal 7
Pass a law to require Mill City Power Company to burn only a high-grade, smokeless coal. The air pollution rate will then

go down to 2 points (it was 10). To pay for the more expensive coal, the company will now charge $600, instead of $400.

Proposal 8
Pass a city law requiring all players to get a "super tune-up" each turn around the board. This will keep air pollution from automobiles as low as possible.

Proposal 9
Build a mass transit system. This will reduce automobile traffic and therefore reduce air pollution. Construction will cost each player $600. Automobile tune-ups will not be required each round.

Proposal 10
Build an improved sewage-treatment plant for Mill City. The new plant would remove solids, harmful bacteria, and most phosphates and nitrates from city sewage. Each player must contribute $150. The Water Pollution Index will go down 15 points.

Make a table to record the proposals you adopt. This written record will remind you of changes in rents and pollution rates.

Proposal	*Company affected*	*Old pollution rate*	*New pollution rate*
4	*Atomic Electric*	*Water 4 points/$400*	*water 2 points/$600*

Extend Your View 24-1
Making it better

Can you modify *The Pollution Game* to make it more realistic? Play *The Pollution Game* a second time. This time your team can design its own Election Ballot. You can also change other parts of the game, such as the "Take a Chance" cards. Use any proposals that you think might improve the situation. For example, you could propose gas-rationing. Or, maybe you would change pollution penalties on certain industries. Or even find an alternative to using cars on the board. Perhaps you can include proposals that are currently being discussed in your community. Also predict how the individual players will act the second time around.

Since the game lacks politicians and government officials, you could invite some prominent member of your municipal government to discuss how the city does or does not take a role in fighting pollution.

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Glossary

adaptable Able to change one's habits to survive in a new environment.
algae Organisms that contain chlorophyll and carry on photosynthesis, but lack true stems, leaves, and roots.
analyze To carefully examine the parts of something to see how they relate to one another.
antibiosis Interactions between two kinds of organism in which one organism produces a substance that harms the other.
aquatic Living in water.

biological community All the organisms that live together in one environment.

carbohydrates Substances, such as sugars and starches, produced by plants during the process of photosynthesis.
carrion The decaying flesh of dead animals.
chemical oxygen demand (COD) The amount of oxygen that will be used up by decaying matter in water.
chlorophyll The substance that gives green plants their color and makes photosynthesis possible.
cilia Hairlike parts of some cells that wave back and forth.
classifying Organizing things into groups on the basis of common properties.
coliform bacteria A group of harmless bacteria found in human intestines. When these bacteria are found in water, it usually means that the water is polluted with sewage.
conservation The planned use of natural resources to prevent their destruction.
controlled experiment An experiment designed to test only one variable at a time.

data The evidence gathered to answer questions.
dormant Inactive.

emphysema A respiratory disease in which the air sacs of the lungs break down.
environment An organism's surroundings.
erosion Wearing away of rock or soil by wind or water.

field The area of a slide that can be seen at one time under a microscope.
flagellum A whiplike part of a microorganism that helps the organism move.
food chain The energy pathway within a community.
food web A group of connected food chains.

germination The sprouting of a seed.

hypothesis A reasonable guess about the connection between two variables.

inference A guess or possible explanation of an observation.

larvae Wormlike young insects.

maze A set of pathways, one of which leads to an end point.
microorganisms Individual organisms that are too small to be seen without a microscope.
mucus A sticky substance produced by the cells that line an animal's air passages.

nutrient agar A jellylike food for growing bacteria and molds.

observation Something that is directly seen, heard, tasted, smelled, or felt.
organism Any individual living thing.

perception A combination of sense data and past experience that makes an organism aware of its environment.
pest An organism that can cause harm or discomfort to other living things.
pesticides Chemicals used to kill pests.

phosphates Substances made up of oxygen and phosphorus. These substances are found in many detergents.
photosynthesis The process in which energy from the sun is used by plants to change water and carbon dioxide into carbohydrates.
potometer A device to measure how fast plants take in water.
predator An animal that habitually kills and eats other animals.
properties Features that help identify an object.

qualitative A type of observation that does not include a measurement.
quantitative A type of observation that includes a measurement.

range The difference between the largest and smallest measurements in a set of data.
reaction time The time it takes for an organism to respond to a signal.
recycled Used again and again.
resistant Not affected or harmed by some organism or substance.
respiration The process used by an organism to release the energy stored in food.

selective breeding Mating organisms with the most desirable properties to produce offspring with those properties.
sense receptors Parts of the body that specialize in receiving signals from the environment.
simulation An experiment that imitates a real-life situation and provides realistic data.
spoil bank A pile of broken rocks and soil produced during the process of strip mining.
sterile (1) Unable to produce offspring. (2) Free from bacteria and other microorganisms.
strip mining Stripping large areas of land to uncover resources near the surface of the earth.

thermal pollution The addition of excess heat to the environment.

variable A factor or property that can change or have a number of different values.

Appendixes A through F

Appendix A
Keys for Extend Your Views

Key 1-1
You are successful in asking questions you can investigate, if

1. you asked at least ten questions.
2. at least seven out of every ten questions you asked called for specific answers, such as "yes" or "no", a number, or an amount.
3. at least half of your questions asked about specific and unusual parts of the situation.
4. most of your questions could be investigated by you (without asking someone else for the answer).

Key 2-1
You were successful if you made ten or more observations. Some of these observations should have been made with a sense other than sight. Have your classmates and teacher help you decide if any of your "observations" were really inferences.

Key 2-2
Some possible questions: "How fast do I breathe when I am sitting still?", "How fast do I breathe after I exercise?", "Does breathing rate increase with age?", "What is the difference between my breathing rate when I am lying down and when I am standing up?"

In describing your method of collecting data you should include:

1. Your method for measuring breathing rate.
2. The equipment you need.
3. Important properties, such as age and sex of the subjects.
4. The behavior of the subjects just before you take the measurements (rested for five minutes, did ten pushups).

Key 2-3
One possible inference is that these fish "prefer" the bottom of the tank. Or, the fish "like" colder water or greater pressure. You could infer that the fish like to hide among the plants. The statement, "There are 12 fish in the tank," is definitely an observation, not an inference.

Key 2-4
1. The players with the striped jerseys are probably moving away from you. The other players seem to be moving toward you.
2. The two players in the center of the photograph probably have a different position on the team.
3. The man with the whistle is probably the referee.
4. The players are touching the ball with their feet; you cannot tell from the photograph whether or not they can also use their hands.
5. There is no way to tell which team is winning.

Key 2-5
Remember that an observation (**O**) is something that you can sense directly. An inference (**I**) goes beyond a simple observation. These are probably the choices you made:

1. **O**	2. **I**	3. **I**	4. **O**	5. **I**
6. **O**	7. **I**	8. **I**	9. **O**	10. **I**

Key 3-1
When he was blind, S.B. was able to concentrate on sounds without being distracted by what he saw. He seemed confident that he could stop the cars with his cane. Apparently, S.B.'s perception of the street changed when he was able to see. He had more information now about traffic than when he was blind. Perhaps his new visual perceptions were strange and frightening, and he lost his old confidence.

Key 3-2
Most people see the lines on the left as curving out at the middle and the lines on the right as curving inward. If you thought the lines were really straight you were probably using your past experience with an optical illusion. You may have thought that someone was trying to trick you into thinking the lines were curved.

You could use a ruler to find out if the lines are really straight. You might compare the distance between the lines at the top and bottom with the distance at the center.

Key 3-3

1. The police officer might think the driver was drunk or using drugs.
2. An auto mechanic might think something was wrong with the car.
3. A driving teacher might think that the driver was just learning to drive.
4. A doctor might think the driver was ill or having a heart attack.

People's training and past experiences affect their perceptions.

Key 4-1

A. earthworm, B. tapeworm, C. hookworm, D. butterfly, E. caterpillar

A, B, C, and E have a similar shape. However, E eventually turns into D, so these two organisms can be grouped apart from A, B, and C.

Key 4-2

You might have used some of the following physical properties: sex, length of hair, if the students were sitting or standing, whether or not they were holding their books. If you knew the students, you could use age, grade level, number of brothers and sisters, or their favorite subjects.

Key 4-3

Whether the man was "dead" or "alive" depends on which properties you use to define death. Some states use lack of brain activity. Others say that death occurs when the heart stops beating. What is the law where you live?

Key 4-4

These organisms are sea anemones (uh NEHM uh neez). These anemones live in the ocean. If you thought they were plants because they look like they have petals or leaves, and seem to have a trunk or stem, that would be a good inference. If you said they were animals because they look like they have a mouth in the middle surrounded by arms, this would also be a good inference. If you said you did not have enough data to make a decision, that was probably the best response. The anemone is classified as an animal. Some anemones are green because they have tiny plants living inside them.

Key 4-5

The range is 45 for both groups. The average is 60 for both groups. Making bar graphs shows a difference. Data for the boys falls into two groups; data for the girls into one.

Key 5-1

Possible *if-variables:* mass, breathing rate, amount of hair or fur, body temperature, kind of food the animal eats. There are many possible hypotheses, but each one should

1. describe a connection between two variables. This can be in the form of an *if-then* statement. Example: If an animal has a greater mass, then its heartbeat rate will be slower.
2. be possible to test. This means you can think of a way to get data needed to support or reject your hypothesis.
3. be more than a summary of the data.

Key 5-2

You were successful if you marked three or four hypotheses correctly. The best responses are:

1. S. The average time for the boys is 6.8 seconds; the average time for the girls is 7.0 seconds.
2. S. The average time for 11 year olds is 7.5 seconds; for 12 year olds, 6.8 seconds; for 13 year olds, 6.6 seconds. Within this narrow range of ages a pattern seems to exist.
3. N. The average time for each group is just about the same (6.9 seconds). Because there is no measurable difference, the hypothesis is neither supported nor rejected.
4. R. The average for the 6 people with greater mass is 7.2 seconds; the average for those with lighter mass is 6.5 seconds. The data shows the opposite of the hypothesis. Therefore the hypothesis is rejected.
5. S. The average time for the 6 taller people is 6.5 seconds compared to 7.2 seconds for the 6 shorter people. A graph of height versus time also shows this pattern. Running time decreases as height increases.

Key 6-1

The first student did not have a controlled experiment. She could not tell if the oxygen had helped the plants to grow. She did not have a setup without oxygen to compare her results with. The second student designed a better experiment. She could compare her treated plants with untreated ones.

In the controlled experiment, the plants continue to grow without the tank of oxygen. This data does not seem to support the hypothesis. However, it is still possible that the roots needed oxygen to grow. But they may have used oxygen that was already dissolved in the water.

Key 6-2

The snails would use oxygen and give off carbon dioxide. The plant in the light (Tube A) would use carbon dioxide and give off oxygen. The exchange of gases would help the organisms survive. If the plant used up all the carbon dioxide that the snails produced, then the blue liquid would not change color. The liquid would turn yellow if the snails produced more carbon dioxide than the plant could use.

In the dark (Tube B), the plant would use oxygen and give off carbon dioxide. The plant would compete with the snails for the oxygen. The blue liquid would turn yellow and the organisms might not survive.

Key 7-1

You might have decided to use two or more goldfish of different sizes and place them in similar containers. The containers should have water from the same source and at the same temperature. After the fish become used to the water, their breathing rates could be counted for 30 seconds. Your *if-variable* is length and your *then-variable* is breathing rate.

You may have thought of other designs. You might have chosen mass for your *if-variable.* You would first determine the mass of a beaker full of water. Then you would add your fish and take another measurement. The difference in the two measurements would be the mass of the fish. This would give you quantitative data on the size of the fish.

Look at the first eight questions in the *Checklist.* The more of these questions you can answer "yes," the better your design.

Key 7-2

Maria's design could have been improved. She identified some variables that could affect the experiment (Item 3 of *Checklist*) but she had not considered others, such as the sizes of each fish or the ages. She inferred that the temperature of the water was the same in each bowl (probably true), but she had not measured it. She did get quantitative data (Item 7), but it would not be wise to come to any conclusion on the basis of only one trial. There was no mention of a method for recording data (Item 8). If Maria had made more trials, she would have needed a way to organize the data (Item 10). Her decision to accept her hypothesis was incorrect, since the data showed the opposite.

Key 8-1

You may have thought of learning tasks involving the finding of food, or an ant's ability to carry different objects. Whatever task you thought of, it should involve an action that

1. the ants can do.
2. can be observed.
3. gives quantitative data.

Key 8-2

Use Questions 1–8 from the *Checklist* on page 86 to help evaluate your experimental design. Your experiment should contain a plan for controlling as many variables as possible. For example, you could use the same subject in two trials. In one trial the subject would study with the radio on; in the second trial the radio would be off. You would need subject matter that could be tested quantitatively, such as vocabulary words. You would need two sets of subject matter of equal difficulty. You also would want to control the time of each trial, the volume of the radio, the content of the radio broadcast (music or news), the temperature of the room, the time of day, and the hunger of the subject. You would not count any trial during which the subject was interrupted by something unexpected such as a loud noise.

With two different subjects, you would have to consider variations in ability to learn the subject matter. You would want to pick subject matter that was equally unfamiliar to both.

Key 8-3

1. Yes. The downward slope of each graph is evidence of learning.
2. Group A probably learned more. The difference between its starting performance and final performance is greater.
3. The steeper slope on the graph of Group A shows that it learned faster than Group B.

4. Group A would probably not do much better on Trial 50 than it did on Trial 10. There is a limit to how fast the rats can run the maze. However, there is the possibility of a slight improvement.
5. One hypothesis might have to do with the curiosity of the animals. That is, at first the rats went through because they were curious about what was at the end of the maze. After the first trials the rats had satisfied their curiosity. But the rewarded rats could eat after each trial. Their desire for food may have improved their performance.

   Another hypothesis might be that the animals dislike being confined. They may just have wanted to find a way out of the maze. But again, the rewarded rats would have the added reward of food.

Key 9-1

Some examples of human needs:

1. People need food. Most people include meat in their diets but others survive as vegetarians through choice or necessity.
2. People sometimes need clothing and shelter to protect them from extremes in temperature. Because of these aids, they can survive within a large range of temperatures. There are people in the frozen Arctic areas and others in the heat of the jungle.
3. People need water. Some of this water comes from the food they eat. This is usually not enough. Most people need a supply of drinking water.
4. People need light for seeing and for growing plants for food.
5. People need room to move around. Their muscles need exercise.
6. People also have social and emotional needs. To meet these needs, most people live in groups.

Key 9-2

During the day it is very hot in a desert. The sidewinder buries itself as protection from direct sunlight. Being covered with sand also hides the sidewinder from its enemies.

During the cool desert nights the sidewinder comes out to hunt. The nighttime activity generates body heat, which helps keep the cold-blooded snake warmer. Also, the heat pits can more easily sense warm-blooded animals when the surroundings are cool. Early morning and evening might present the ideal temperatures for the sidewinder.

Key 10-1

D. This area provides the most favorable light conditions, not too bright or dark.
A. Red light from the food coloring might attract euglenas, but probably not as much as shaded sunlight does.
B. Euglenas tend to move downward away from direct sunlight.
C. Few euglenas would be attracted to the dark area under the boat.

You could test your predictions by taking samples of water from the four areas of the pond. You could then compare the number of euglenas in each sample.

Key 10-2

Some light is necessary for food production, but direct sunlight can be harmful. The organisms come closer to the surface at twilight and dawn. They avoid the surface at midday. At night, when there is little light, they would move in no particular direction.

Key 11-1

Your plan should include these steps:

1. You expose your seeds either to several temperatures, to light and darkness, or treat some seeds to help them absorb water.
2. You expose at least ten seeds to each condition.
3. You make daily observations and record them.

After you do your experiment, describe the conditions that made the most seeds germinate in the least time.

Key 12-1

The cholla is a cactus that grows in the southwestern United States. In a dry climate, water loss must be kept to a minimum. Instead of leaves the cholla has spines. Spines have a much smaller surface area than broad leaves. This reduces the water loss during dry times. The cholla cactus also has a thick stem for storing water.

The oak grows in regions where there is an ample supply of water. The tree does not have to

store water. Therefore, the oak's leaves can be broad and have a large surface area. The leaves fall off in the fall. This helps control water loss during the winter.

Key 13-1
If the Jacksons add larger fish to the lake, these fish may eat the medium-sized fish. Or they may eat the smaller fish on which the medium-sized fish feed. Either way there might be fewer medium-sized fish to catch. A new balance will be established. But it is hard to predict in advance how many large or medium-sized fish there will be in the new food web.

Key 13-2
This might be a good technique to keep coyotes from eating sheep. The coyotes would still be able to eat the other foods such as rabbits and rodents. Other predators might also learn not to eat sheep, which would help the sheep rancher. But coyotes might learn that live sheep do not contain the chemical. Dead sheep are usually left on the range and are eaten as carrion by many kinds of organism. If the animals that usually eat carrion do not eat the dead sheep, this will affect the food web. And what happens after the six-week period?

Key 14-1
You should advise your friend not to buy the chili. The bulging ends of the can probably mean that there is gas inside. You could infer that the gas is produced by microorganisms growing on the chili. (Remember the gas bubbles when the hamburger decayed.) Canning is supposed to prevent the growth of microorganisms. But sometimes the canned goods are not properly prepared. If the cans have not been heated to a high enough temperature or for a long enough time, microorganisms can continue to grow.

Key 14-2
The extreme low temperature in Siberia prevented the growth of microorganisms and the decay of the mammoth.

Key 14-3
If plants and animals did not decay, they could easily be stored and shipped to hungry people. But the chemical also would cause the surface of the earth to become cluttered with dead organisms. Microorganisms would not be able to break them down. Also basic chemicals would not be recycled. The soil could no longer support the growth of plants.

Key 15-1
One experiment would be to place healthy fish (of the type that had been found washed ashore) in two containers of ocean water. One container would have water from which Jim Brevis had been removed. The water in the other container would not have contained Jim Brevis. Otherwise the water would be similar.

If only the fish in the Jim Brevis water died, this would indicate that antibiosis was most likely the cause of death. If your experiment is different from this one, ask your teacher to help you evaluate it.

Key 15-2
The creosote bush roots could give off a substance that kills the seedlings. New plants would continue to grow only if they were beyond the range of the substance. The death of the seedlings reduces competition for the scarce desert water. The even spacing increases the chances for survival of the remaining creosote bushes over long periods of time.

If you made a different hypothesis, ask your teacher to help you evaluate it.

Key 16-1
1. The team was trying to return the environment to its natural state—to the conditions that existed prior to the arrival of the Clarionites.
2. Perhaps the team felt that this was the lowest acceptable environment for the survival of Clarionites.
3. Perhaps the team felt that the environment could be made better than its natural state. For example, planting trees on hillsides might reduce erosion.

Key 16-2
Each proposal has its weak points. Project 1 must be used every round. Project 2 takes just as long, but it does not need to be used every round. Project 2 would do less harm to the environment. Project 2 would also conserve fuel.

Key 17-1
1. Suppose you chose an existing dam to study. You can compare your list of conclusions with those of your classmates who studied the same

dam. Did you list the changes in the plant and animal life, the nearby towns and cities and the farms, both upstream and downstream from the dam? You probably inferred changes in the terrain from the reservoir, or changes in the river itself. You could have inferred that the dam has changed the amount of energy available to nearby communities. Different kinds of animals may now live in the area.

2. You might have inferred that the dam was built for a power source, for flood control, to provide a reservoir for drinking water, or for recreation. You could check your inferences by writing to a local government agency or by reading about the dam in books, magazines, or newspapers. If the dam has not been built yet, you will have to wait to check your inferences.

Key 18-1

Chipped paint, a scuff mark, or objects that did not exist when the school was built are evidence of changes. You must infer that the change happened. For example, paint does not chip until after it has dried. Your second change could have been an opened window, the lights being on, or an erased chalkboard. There may have been writing on the board the last time you were in the room.

Key 18-2

Energy flow occurs when the energy output is different from the energy input. Some examples of energy flow:

1. Light from the sun is changed to electricity by the solar cell.
2. Electricity is changed to wind by the fan.
3. The motion of the matchcover against the match is changed into heat and light.

Smoke and ash from the burning trash would be examples of pollution.

Key 18-3

You might have chosen some of these examples of disruption:

1. If electricity stops, there are no lights. If traffic lights are not working, traffic would not flow smoothly. Without house lights, people would have to use candles or flashlights to move about at night.
2. Elevators would stop running. Some people might be trapped in elevators. Others might not be able to climb the stairs to their apartments.
3. Electric refrigerators in homes, stores, and warehouses would stop working. After about a day, the food would begin to spoil.
4. People in homes heated by electricity would have to use blankets, extra clothing, or fireplaces.
5. Gas stations depend on electricity to pump fuel. If trucks could not get fuel, food deliveries would stop.

Key 19-1

You could set up a sampling program that would

1. survey the entire community.
2. gather data on amounts of pollution.
3. map the distribution of pollution.
4. identify sources of pollution.

Discuss any other suggestions with your teacher.

Key 19-2

You might have put the photographs in this order:

D) person spraying trees; heavy concentration of insecticide.
A) police officer; city intersection with car exhausts.
C) man jogging; outdoors, suburban, but near road.
G) students playing field hockey; indoors and very active.
B) girl studying; indoors but more active than baby.
F) boy fishing; outdoors with no visible air pollution.
E) baby sleeping; probably indoors.

You could also reason that either (E) and (F) or (B) and (F) could be switched. To make a more accurate determination, it would be necessary to know more about each environment.

Key 19-3

To test the hypothesis in a laboratory, you would need

1. to identify the types and amounts of automobile-exhaust gases along the highway.
2. to expose corn plants to these same types and amount of gases.

3. other corn plants growing under the same conditions, except without exhaust gases.
4. a way to measure results, such as observations of height, rate of growth, leaf color, number or size of ears of corn produced, or the quality and size of the corn kernels.

You might have decided to observe corn plants in the field. Your design should still include Items 3 and 4. Discuss your idea with your teacher.

Key 19-4

The graphs show that more smokers than nonsmokers die from lung cancer. Also, as smoking becomes heavier, the death rate increases. The larger the city, the greater the chance that a nonsmoker will get lung cancer. But whether or not people smoke is a more important variable than where they live.

Key 20-1

The data indicates that Lake Erie is more polluted than Lake Ontario. The table shows that Lake Erie has

1. a higher chemical oxygen demand.
2. more coliform bacteria.
3. more phosphorus.
4. more algae.

Key 20-2

The best answers to the questions probably are:

1—N	5—N	9—M	13—M	17—M
2—M	6—Y	10—Y	14—Y	18—N
3—Y	7—N	11—N	15—M	19—Y
4—M	8—Y	12—Y	16—Y	20—M

If you have other answers, discuss them in class.

Key 20-3

Plan A You probably do not know whether or not chlorine compounds are harmful to living things. Chlorine compounds may cause pollution, too.

Plan B This plan just sends the undesirable substances somewhere else, where they will become a problem for other people and aquatic organisms.

Plan C This is probably the best plan. If Crystal City is going to reduce pollution in the lake, its citizens must stop using products that cause pollution.

Key 21-1

There are no right or wrong answers to this item. Your ideas will probably depend on what forms of energy you think you need or can do without. Some of the suggestions you may have made are:

1. Hanging clothes outdoors in good weather instead of using a clothes dryer.
2. Restricting the use of transportation to "business" trips. Walking or using a bicycle are alternatives.
3. Living at a slightly higher temperature in the summer and a slightly cooler temperature in the winter.

Some of the changes might affect jobs. For example, consider those people who make air conditioners and automobiles. People may have to spend more of their time getting from one place to another or doing routine tasks such as laundry.

Key 21-2

The specific answer to this item will depend on your community. Your discussion should have included the following factors:

1. Cooling method. Is there a source of water near your school? Would towers have to be built?
2. Environmental impact. How is the land being used now? Would there be any thermal pollution?
3. Cost. Would the cost of a plant at this site compare favorably with the cost to build at another site?
4. Need for energy. How badly does your area need more electricity?
5. Safety. Is there a danger of radiation leakage?

Key 22-1

You might want to know:

1. How soon is the oil needed? How much faster could the Alaska Pipeline be constructed than the Canadian Pipeline? Could other sources of energy be used instead of oil?
2. Since the Canadian Pipeline would cross Canada, the United States would have to work out details with Canada. How does Canada feel about each pipeline? Will Canada benefit from either pipeline?
3. What kind of environment would both pipelines cross? What might be the effects on plant and animal life? What are the chances of oil

leaking into the environment? How would an oil spill affect the environment?

This problem is complex, just like *The Redwood Controversy.*® Probably not everyone will be satisfied with either solution. It is difficult to solve this problem because a decision must be made before all the data can be gathered.

Key 23-1

1. People who make dandelion wine would not consider dandelions to be pests. People who want a grassy lawn would probably consider dandelions a pest.
2. The farmer may consider the corn a pest because it makes it harder for him to harvest the soybeans. The corn is a pest to the soybeans, because the corn competes with the soybeans for light, water, and other nutrients.
3. The insects would probably consider people who drive automobiles pests. The people are interfering with the natural environment of the insects.
4. The children are pests to the fireflies when they remove the fireflies from their natural environment.
5. To the carrots, corn, and the gardener, rabbits are pests. To the hunter, however, rabbits are not pests. They are a source of food and recreation. Rabbits would consider rabbit-hunters pests.

Key 23-2

Decisions of this kind are hard to make. You should compare the citizen's committee's proposal with other alternatives for getting rid of the mosquitoes. For example, a predator might be put in the swamp to eat the mosquito larvae. You will have to decide how serious the problem is. Are the mosquitoes simply a nuisance or are they a threat to health? If the spray is a hard pesticide, it could damage the environment. Also the pesticide may only work for a short time. Perhaps some mosquitoes will be resistant to the spray. If the mosquito problem is serious, there may not be time to develop and test other control methods.

Key 24-1

Discuss your game with the rest of the class. Decide which proposals would most likely be adopted by your own community. Which solutions could be handled on the local level? Which solutions would need state or federal action? Are there any proposals that need the cooperation of other countries?

Appendix B
The metric system

Some common metric units

	Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Energy	joule	J
Temperature	Celsius	°C

Commonly used prefixes

Prefix	Meaning	Symbol
kilo-	1000	k
centi-	0.01	c
milli-	0.001	m

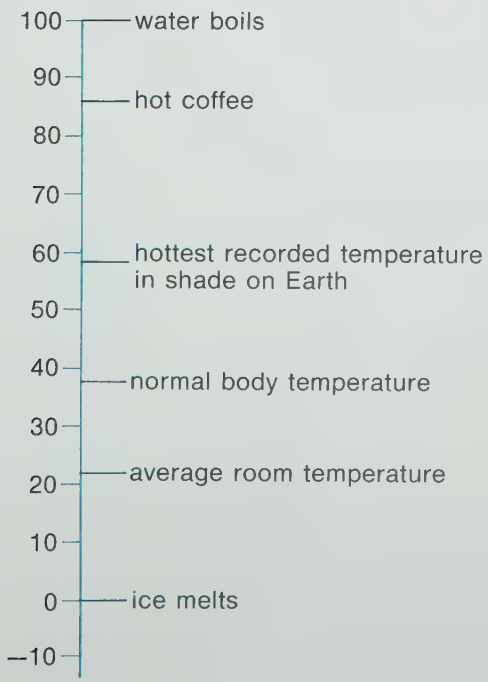


Table of metric units

	Unit	Value	Symbol	Approximate magnitude
Length	kilometre	1000 m	km	8 city blocks
	metre	unit	m	height of a drinking fountain
	centimetre	0.01 m	cm	radius of a nickel
	millimetre	0.001 m	mm	thickness of a dime
Mass	tonne	1000 kg	tonne	mass of a subcompact car
	kilogram	unit	kg	mass of a full can of motor oil
	gram	0.001 kg	g	mass of 3 aspirin tablets
	milligram	0.001 g	mg	mass of 10 crystals of table salt
Area	hectare	10 000 m^2	h	area of a football field
	square metre	unit	m^2	area of the top of a card table
	square centimetre	0.0001 m^2	cm^2	area of the colored part of your eye
Volume	cubic metre	unit	m^3	volume of 3 bathtubs
	litre	0.001 m^3	l	volume of a can of motor oil
	cubic centimetre	0.000 001 m^3	cm^3	volume of 2 nickels
	millilitre	0.001 l	ml	
		$cm^3 = ml$		
Energy	joule	unit	J	energy to raise the temperature of a raindrop 5°C

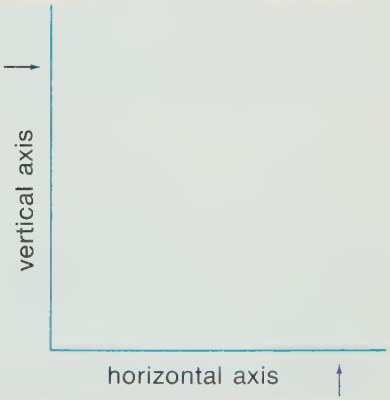
Appendix C
How to graph data

This program of instruction will help you learn to make a graph. It consists of 30 numbered parts. Each part is called a "frame." Each frame gives you some information or a technique that will help you understand the contents of the following frames.

To begin, cover everything on the page below Frame 1 with a sheet of paper. Read the contents of Frame 1 and answer the questions on a separate sheet of paper. Do not write in the book. Then uncover the printed answer to Frame 1. If your answer is correct, go on to Frame 2. (Move your paper until you reach the next blue line.) If your answer is not correct, reread Frame 1 to discover why. When you are able to correct your answer, go on to the next frame. If you have any problems that you cannot solve, ask your teacher for help.

1.

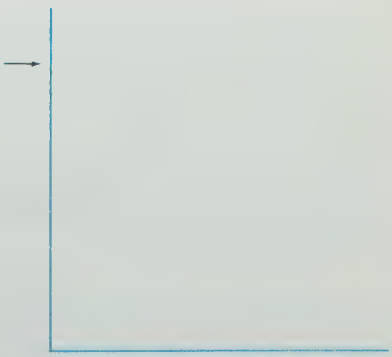
The diagram shows two lines that make the border of a graph. The border has two parts. They are the _____ and the _____.



2.

Answer 1. vertical axis, horizontal axis

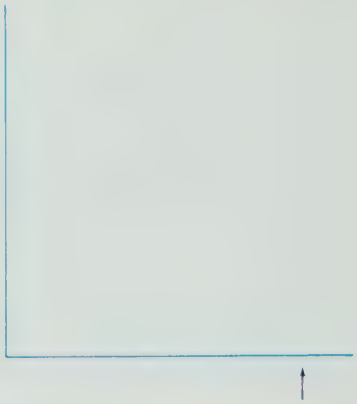
The arrow in the diagram points to the _____ axis.



3.

Answer 2. vertical

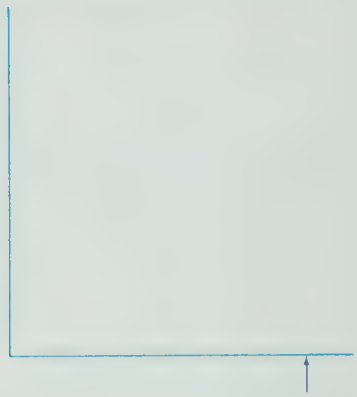
The arrow in the diagram points to the _____ axis.



4.

Answer 3. horizontal

On your sheet of paper, make a pair of axes similar to those in this diagram. Label each axis with its proper name.

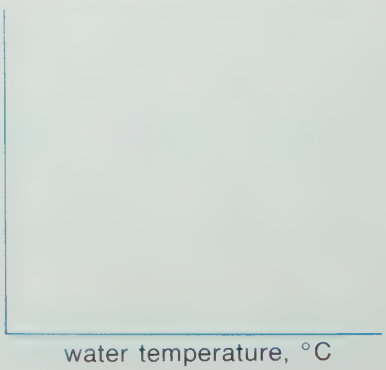


5.

Answer 4. Your graph should look like the one in Frame 1.

water temperature, °C	*5*	*10*	*15*	*20*	*25*
heartbeats per minute	*5*	*15*	*26*	*35*	*43*

This table contains data from an experiment on goldfish. The horizontal axis in the diagram is labeled with one of the variables, "water temperature." One of the variables is used to label the _____ axis.



6.

Answer 5. horizontal

The horizontal axis is usually labeled with the *if-variable.* What is the *if-variable* in the goldfish experiment?

7.

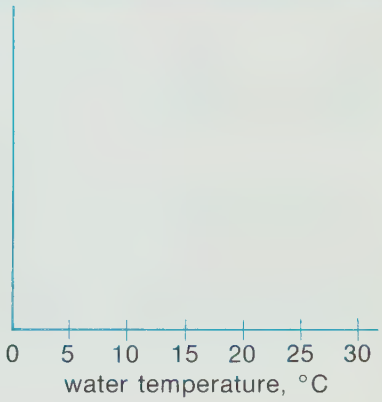
Answer 6. water temperature

Look at the data-table again. The water temperature ranges from _____ to _____.

8.

Answer 7. 5°C to 25°C

The water temperatures are on the _____ axis as shown in the diagram.



9.

Answer 8. horizontal

Look again at the diagram in Frame 8. The horizontal axis has been divided into segments (units of length). These segments represent _____.

10.

Answer 9. water temperatures

In the diagram in Frame 8, the distance on the horizontal axis from 5°C to 10°C represents _____ degrees of temperature.

11.

Answer 10. 5

In the diagram in Frame 8, each segment of the horizontal axis has been set up to represent _____ degrees of temperature.

water temperature, °C	5	10	15	20	25
heartbeats per minute	5	15	26	35	43

12.

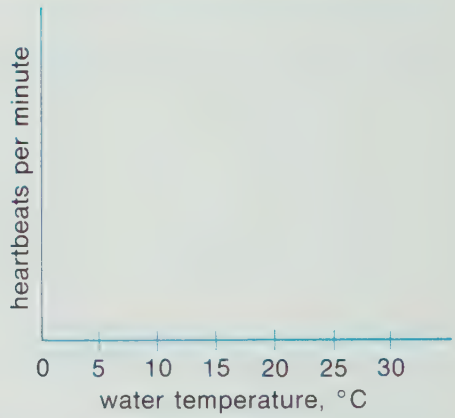
Answer 11. 5

In the diagram in Frame 8, the length of the segment from 15°C to 20°C is (equal/unequal) to the length of each of the other segments.

13.

Answer 12. equal

In this diagram, the vertical axis is labeled with the second variable from the data-table, "heartbeats per minute." This variable is used to label the _____ axis.



14.

Answer 13. vertical

The vertical axis is usually labeled with the *then-variable.* Which variable in the data-table is the *then-variable?*

15.

Answer 14. heartbeats per minute

Look at the data-table again. The number of heartbeats counted per minute ranges from _____ to _____.

16.

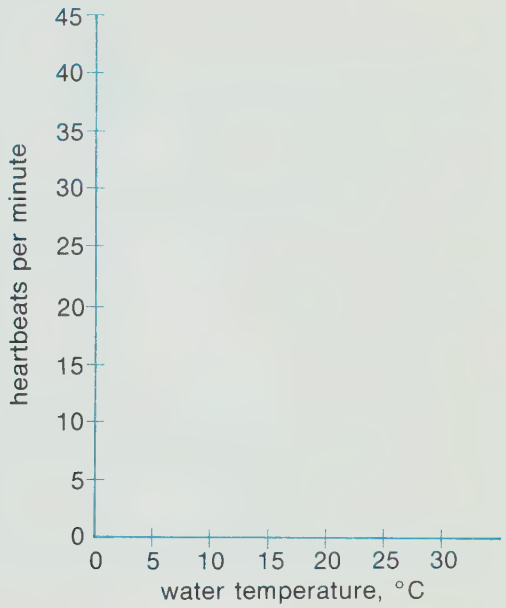
Answer 15. 5 to 43

The number of heartbeats is recorded on the _____ axis.

17.

Answer 16. vertical

On the vertical axis in this diagram, the segment numbered 0 to 5 represents _____ heartbeats per minute.



18.

Answer 17. 5

Each segment of the vertical axis in the diagram in Frame 17 represents _____ heartbeats per minute.

19.

Answer 18. 5

On the vertical axis in the diagram in Frame 17, the length of the segment from 0 to 5 is (equal/unequal) to the length of each of the other segments.

20.

Answer 19. equal

Each segment of the horizontal axis represents _____°C, and each segment of the vertical axis represents _____ heartbeats per minute.

water temperature, °C	5	10	15	20	25
heartbeats per minute	5	15	26	35	43

21.

Answer 20. 5, 5

Examine the two sets of numbers in the data-table. At 5°C, 5 heartbeats per minute were counted. At 10°C, 15 heartbeats per minute were counted. The number of heartbeats counted at 15°C, 20°C, and 25°C were _____, _____, and _____.

22.

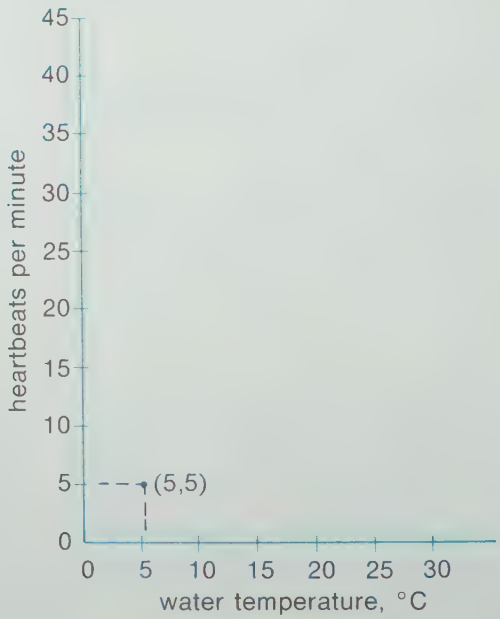
Answer 21. 26, 35, and 43

The numbers from the data-table can be considered in pairs. For example, at 5°C there were 5 heartbeats per minute. Therefore 5 and 5 are a pair of numbers. The other pairs of numbers from the table are _____ and _____, _____ and _____, _____ and _____, _____ and _____.

23.

Answer 22. 10 and 15, 15 and 26, 20 and 35, 25 and 43

Each pair of numbers can be plotted or represented by a single dot. The dot on this diagram represents the number pair 5 and 5. The number pair is represented on the diagram by a _____.



24.

Answer 23. dot

On the diagram in Frame 23, a dashed line drawn from the dot to the horizontal axis points to a water temperature of _____.

25.

Answer 24. 5°C

On the diagram in Frame 23, a dashed line drawn from the dot to the vertical axis shows that _____ heartbeats per minute were counted.

26.

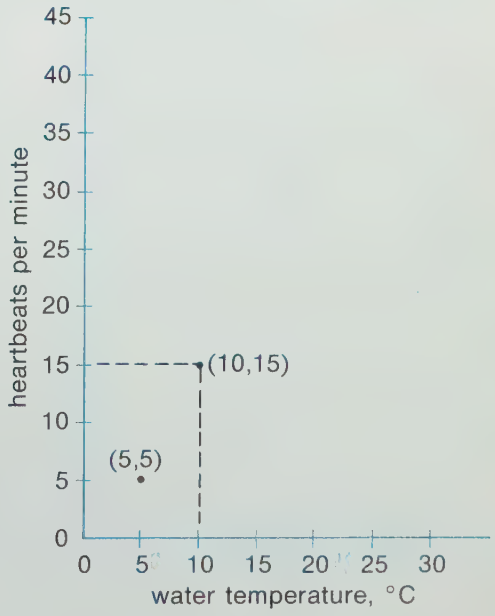
Answer 25. 5

The position of the dot in Frame 23 shows that when the water temperature is _____, the number of heartbeats per minute is _____.

27.

Answer 26. 5°C, 5

To place the dot for the number pair 10 and 15 on this diagram, a dashed line is drawn from a water temperature of _____ on the horizontal axis. A dashed line is drawn from _____ heartbeats on the vertical axis.



28.

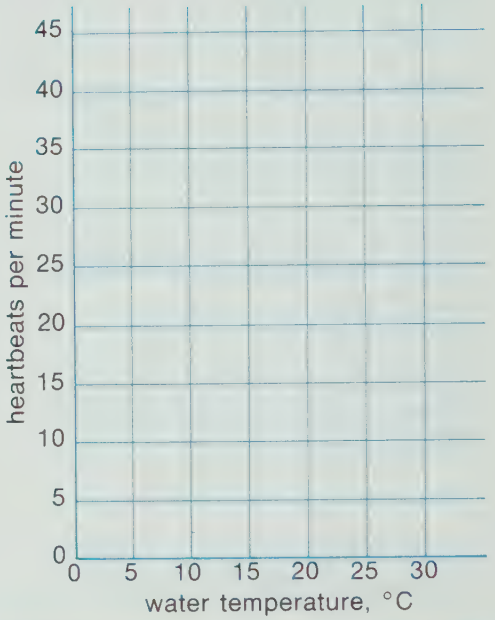
Answer 27. 10°C, 15

Where the two dashed lines meet on the diagram in Frame 27, the number pair 10 and 15 is represented by a _____.

29.

Answer 28. dot

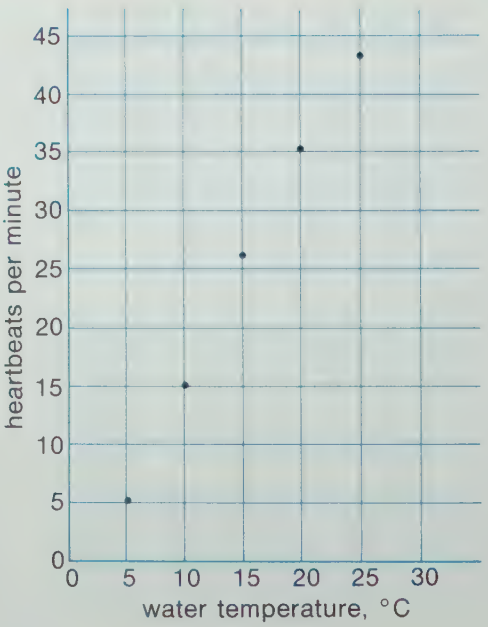
On a sheet of paper, copy this diagram, including the labels. Then place the dots to represent all the number pairs: 5 and 5, 10 and 15, 15 and 26, 20 and 35, 25 and 43.



30.

Answer 29. See Frame 30.

When you have placed all the dots, your diagram should look like this. You can connect the dots with straight lines. This diagram is called a graph. The graph shows how the heartbeat rate of a goldfish and water temperature are related.



By completing this program, you have made a graph of the data. The data is now represented by dots. A data-table is one way to organize data. The graph you just made is another.

Appendix D
Learning to use the microscope

You should be able to learn to use a microscope by yourself. But if you need help, ask your teacher. You will probably be sharing the microscope with other students. A microscope is an expensive piece of equipment. It is important to take care of your microscope.

Materials
microscope
several microscope slides and cover slips
lens paper
medicine dropper
forceps

Making a wet mount

Find something you want to observe. It might be hair, aquarium water, a leaf, or just about anything. Select a tiny bit of the substance. It must be thin enough for light to pass through. The slide you will make is called a wet mount because the object being observed is placed in a drop of water.

Set a slide down on a flat surface. The object that you want to observe may be picked up and put on the slide with forceps. Put enough water onto the object to cover it, probably one or two drops. If you are looking at a liquid such as pond water, put one drop of the liquid on the slide (Figure 1).

If some students select substances that you know are soluble in water, let them proceed. They will learn one of the limitations of the microscope.

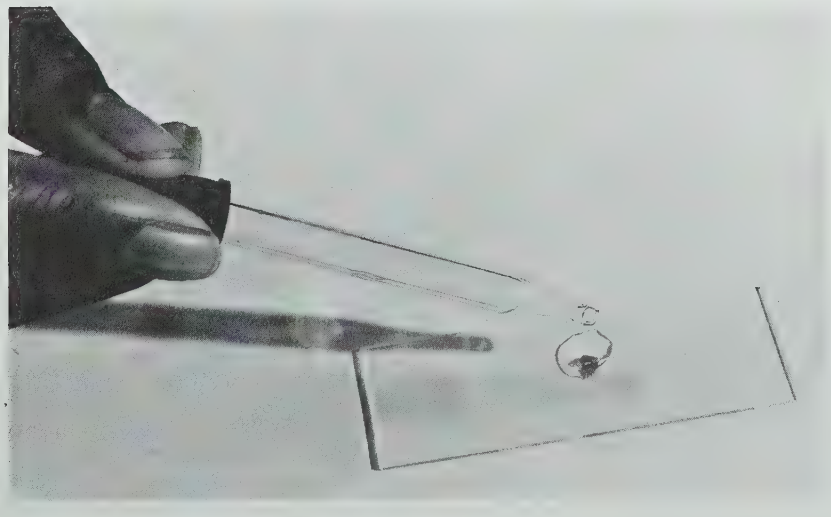
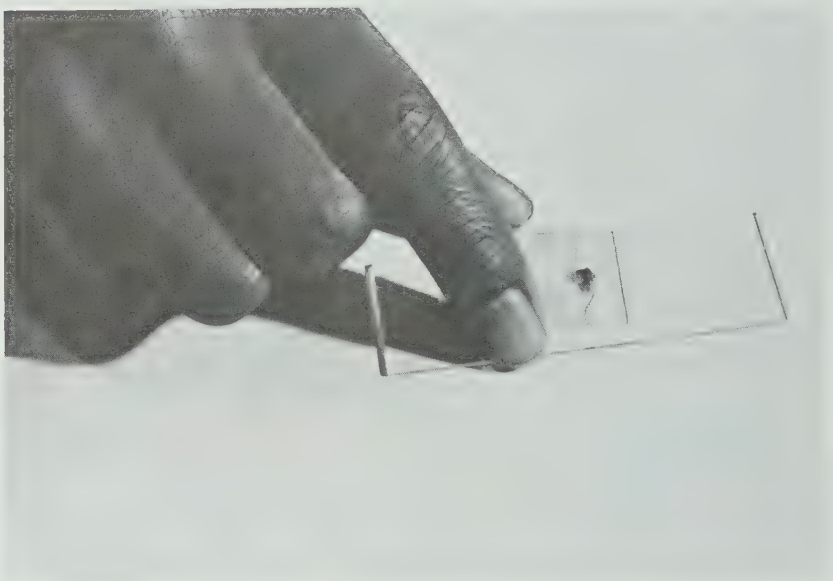


Figure 1

Pick up a cover slip, holding it by two edges. Put one edge of it beside the drop of water on the slide. Slowly lower the cover slip. The water should flow under it. This method will prevent lots of bubbles from getting under your cover slip. The slower you lower the cover slip, the fewer bubbles you should have (Figure 2).

Figure 2



Using the microscope

Set aside your wet mount and get a microscope to use. Carry the microscope upright with both hands. Hold the microscope by its arm and base (Figure 4). Always set the microscope away from the edge of the table and keep it there. Your microscope may be somewhat different from the one in the pictures. But it will probably be similar enough for you to follow the procedures. Tilt the arm back and carefully clean the lenses. Wipe them only with the lens paper your teacher supplies. Tilt the arm to its original position.

Make sure the lowest power objective (usually 5X or 10X) is under the body tube. Turn on the light under the stage. If your microscope has a mirror instead, look through the eyepiece and adjust the mirror to reflect light up through the hole in the stage (Figure 5). You should see a bright circle of light. If you move the microscope you will need to readjust the mirror to get the best lighting. Keep the microscope out of direct sunlight.

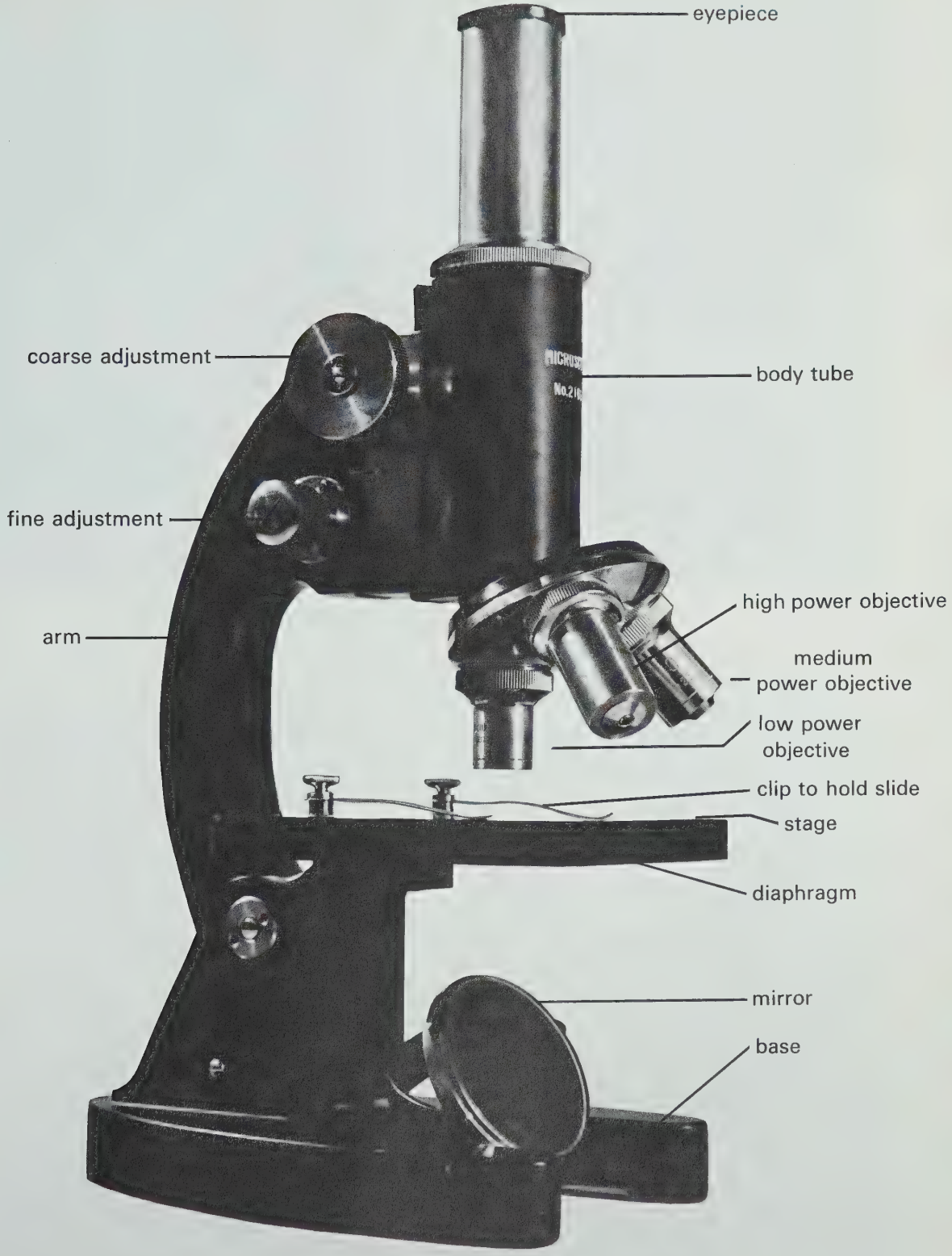

eyepiece
coarse adjustment
body tube
fine adjustment
high power objective
arm
medium
power objective
low power
objective
clip to hold slide
stage
diaphragm
mirror
base

Figure 3



Figure 4



Figure 5

Raise the body tube with the coarse adjustment. The low power objective should be at least two centimetres above the stage. Set the slide so that the substance you will observe is above the center of the hole in the stage (Figure 6). Hold the slide in place with the clips. Lower the body tube as you watch from the side (Figure 7). Stop when the objective is about one-half centimetre above the slide.

Look through the eyepiece (Figure 8). Slowly raise the body tube with the coarse adjustment until the substance on the slide comes into view. If you miss it, start again by lowering the body tube as you watch from the side. Also, check to see if the substance is centered directly above the hole in the stage. Be sure to raise the tube to get the slide in focus.

Caution: Do not focus downward when using the coarse adjustment. You could break the slide and damage the objective lens.

Use the fine adjustment to bring the substance into sharper focus (Figure 9). Move the slide around slowly to observe all of the substance. Turn the fine adjustment up and down just a little as you move the slide. Adjust the light with the diaphragm (DY uh fram) until you see the substance as clearly as possible. To avoid eyestrain, try to keep both eyes open as you look through the eyepiece. This may be hard at first, but soon you will find it easy.



Figure 6

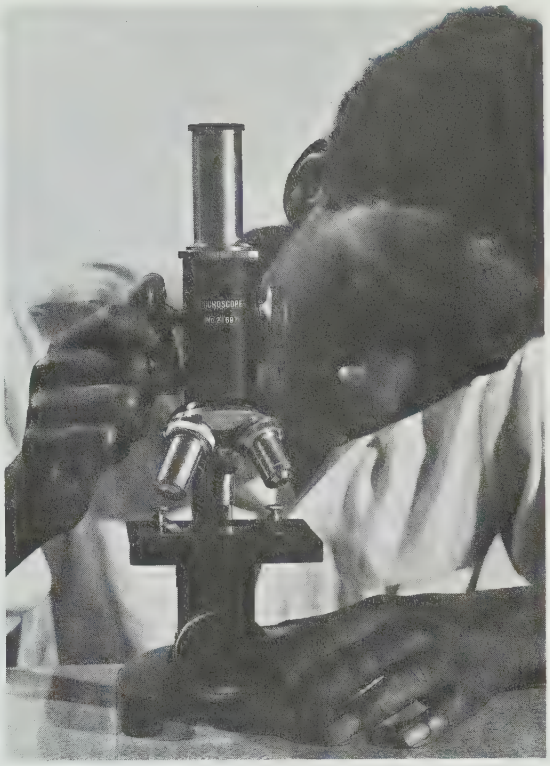


Figure 7

Figure 8

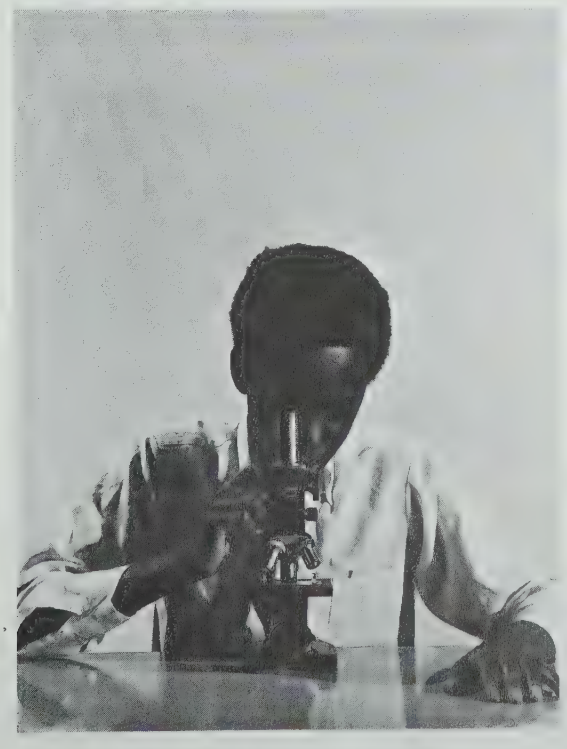


Figure 9



To increase the magnification, rotate the next higher power objective under the body tube (Figure 10). You do not need to move the body tube. The substance should automatically be in focus. If you move the slide around, use only the fine adjustment to adjust the focus. The higher power objectives do not let as much light through as the low power objective. Therefore, you may need to adjust either the mirror, the diaphragm, or both to get more light. Or you may have to make another slide using thinner material.

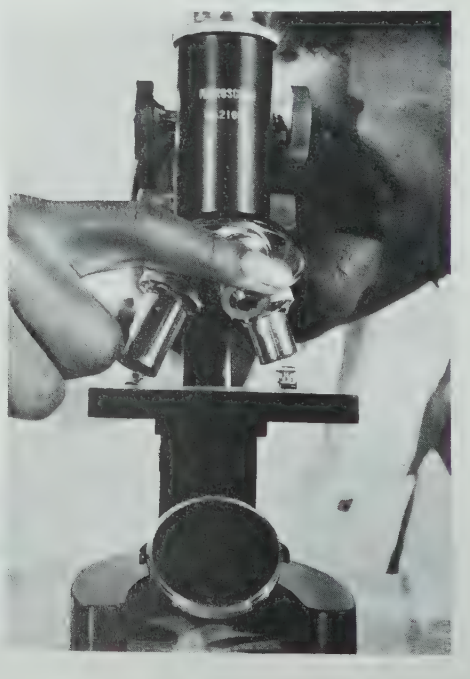
When you have finished observing, rotate the low power objective back under the body tube. If you want to look at another slide, repeat the procedures, starting with placing the slide on the stage (Figure 6). If you do not want to look at another slide, clean and dry the slide.

Before putting the microscope away, always remember to check these points.

1. The low power objective is under the body tube.
2. The objective is lowered to about one centimetre from the stage.
3. The body tube is upright.
4. The diaphragm is wide open.
5. The objectives and stage are clean and dry.

Remember to hold the microscope upright by its base and arm as you carry it.

Figure 10



Appendix E
Careers

The careers in this appendix are only a sample of careers that use the skills you are learning in this program. They were chosen to show you the variety of possible careers. Some of these careers require a college education. For others, you need vocational or on-the-job training. In the column labeled "Preparation and Qualifications," you will sometimes find the words "advanced degree." These degrees take from one to five years of further study after four years of college. If you want more information on any of these careers, see your guidance counselor or librarian.

Career Description	Preparation and Qualifications
Accelerator Operator Sets up and coordinates the operation of particle accelerators in nuclear plants. Adjusts machine controls as instructed by a supervisor and sets up target materials. Assists in the maintenance of equipment.	Needs a high school diploma, with courses in mathematics and physics to qualify for on-the-job training.
Agricultural Engineer Designs and develops equipment and methods for use by farmers. Must make and test working models. May supervise the production of the equipment. May develop irrigation systems and methods for soil or water conservation.	Usually works in a laboratory or factory but often spends time on farms. Needs four years of college, with a major in engineering. An advanced degree is useful.
Animal Care Technician Helps do experiments, keep records, and prepare reports of animals' reactions to tests. Assists veterinarians in care of sick animals.	Works for medical schools, research centers, veterinarians, and drug companies. Must like animals, have an interest in biology, and be precise in recording data. Needs two years of college or technical school.
Aquatic Biologist Studies plants and animals living in water and the environmental conditions affecting them.	Needs four years of college for a beginner's job and an advanced degree for a more responsible position.
Biochemist Studies the chemical processes of living organisms, and the effects of food, drugs, and hormones on life processes. May be involved in basic research on the nature of living things or applied research to solve a problem.	Works in a laboratory, often with complicated equipment. Needs four years of college with a major in biochemistry or biology for employment as a research assistant. Needs an advanced degree for positions of greater responsibility. Skill and training in mathematics are useful.

Career Description	Preparation and Qualifications
Cooperative Extension Service Worker Is involved in educational work in agriculture, home economics, youth activities, and community resource development.	Is employed jointly by state land-grant universities and the United States Department of Agriculture. Must like to work with and help other people. Needs four years of college and training in educational techniques.
Ecologist Studies effects of climate, weather, location, food supply, and competition on plants and animals. Uses knowledge of interactions between organisms and environment for conservation purposes.	May spend time both in a laboratory and outdoors. Needs four years of college with a major in life science or ecology.
Experimental Psychologist Designs and does experiments to study animal behavior, including the behavior of people. Studies how variables affect growth, intelligence, learning, personality, and perception.	Works in a laboratory, often at a university. Should be able to communicate ideas, and work with laboratory animals. Needs an advanced degree in psychology.
Farmer Manages land used for the production of plants and animals for food. Works with large field equipment such as tractors and harvesters.	Invests money in land and equipment. Generally works outdoors. Working on a farm is useful. High school courses and intensive training programs are available. College training in agriculture and agricultural business management helps the farmer keep up with new research and technology.
Fish and Wildlife Specialist Studies animals to find the best methods to conserve or increase populations. Tries to prevent the extinction of species. Attempts to reduce stream pollution and restore vegetation.	Must balance the needs of animals with the needs of sport and commercial hunters and fishermen. Often works outdoors and in remote areas. Needs four years of college, with a major in biology and an advanced degree in a specialized field.
Fish Culture Technician Collects data about fish—their growth, migration, food, and enemies. Studies water conditions where fish live and breed, and duplicates these conditions in fish hatcheries to stock lakes and streams. Raises and breeds fish. Cares for eggs, feeds young fish, and cleans ponds.	Needs two years of college or technical school. Government workers must pass a civil service examination.
Food Scientist (Food Technologist) Determines the composition of food. Develops new methods to process and preserve food. Tests food for quality and safety.	Usually works in commercial or university laboratories or in processing plants. Needs four years of college, with a major in food technology, chemistry, or biology. An advanced degree is useful.

Career Description	Preparation and Qualifications
Food Technician Assists food scientists in research and in processing plants to assure the quality of the product. Makes sure foods are stored at the proper temperature and processed under sanitary conditions. May perform biological or chemical tests, or prepare reports. Often uses instruments such as balances, sterilizers, and microscopes.	May be employed by state and federal governments or by food processors. In some specialties, state licensing is required. Needs at least a high school diploma with courses in biology, chemistry, and mathematics. Often needs additional education at a technical school or junior college.
Forester Manages, develops, and protects forest resources for economic and recreational purposes. Supervises the cutting of trees, the marketing of forest products, and reforestation.	Needs four years of college with a major in forestry. Needs an advanced degree for research or teaching. Government-sponsored summer work programs are available.
Forest Technician Prepares surveys on timber production, recreation, wildlife, or water regulation. May be involved in protecting forests from insects, disease, or fire.	May work for the government or lumber companies. Needs physical stamina, manual skills, and enjoyment of the outdoors in all kinds of weather. Needs at least a high school diploma. A two-year college program is desirable.
Horticultural Technician Assists in flower production and sales, growing plants, construction and care of lawns, or planting and care of trees in parks.	Works outdoors at least part of the time. Needs two years of college or technical school.
Horticulturist Works with orchard and garden plants. Develops new or improved varieties of fruits, nuts, vegetables, flowers, and bushes. Finds the best method of growing, harvesting, storing, and transporting plants and crops.	Usually spends some time at a desk, some time in a laboratory, and some time outdoors. Needs four years of college to qualify for a beginner's job, but an advanced degree is necessary for a more responsible position.
Landscape Architect Plans and designs sites for private homes, businesses, and public areas. Draws site plans and makes cost estimates.	Must know about suitable plants and construction materials. Should like art and nature, outdoor work, and travel. Drafting skills are useful. Needs four years of college. Apprenticeship programs are available.
Livestock Production Technician Assists in the breeding, raising, and marketing of cattle, sheep, and hogs.	Works on farms, in the feed and equipment industries, and in veterinary medicine. May work outdoors in varying kinds of weather. Needs at least two years of college with courses in nutrition, genetics, physiology, and business.

Career Description	Preparation and Qualifications
Marine Life Technician Gathers, sorts, classifies, analyzes, and breeds organisms that live in salt water.	May work for aquariums or oil companies interested in underwater drilling. Some jobs involve scuba diving. Most jobs require only short periods at sea, but long, irregular hours may be required. Needs at least a high school diploma with courses in mathematics and science. Two years of college is desirable.
Meteorologist Studies and interprets atmospheric conditions to forecast the weather.	May be involved in research, or work for industries that are dependent on weather conditions. May have irregular work hours and assignments at remote stations. Usually works as part of a team. Needs four years of college with a major in meteorology, science, or engineering. A knowledge of computers is helpful.
Microbiologist (Bacteriologist) Studies bacteria and other microorganisms. Observes their growth, structure, and development, and their effects on other organisms. Isolates and makes cultures of microorganisms. Analyzes the substances produced by microorganisms.	Needs precision and manual skills. May specialize in fields such as virology, food bacteriology, pharmaceutical bacteriology, or medical bacteriology. Needs an advanced degree in bacteriology.
Nuclear Reactor Operator Watches reactor control panels to maintain correct operating conditions.	Must be licensed; must pass written test and medical examination. Needs at least a high school education. Most begin as boiler or turbine operators in non-nuclear power plants.
Nursery Manager Manages a nursery to grow trees, shrubs, and flowering plants. Uses knowledge of plant germination, soils, growing habits of plants, and marketing techniques. Supervises workers.	Needs a high school diploma. Summer work while in high school is useful. Technical schools offer courses in botany, plant pathology, and horticultural landscaping.
Orchard and Vineyard Technician Helps grow and harvest fruits, nuts, or grapes. Studies soil composition, lighting, moisture, and pruning to find the most favorable conditions for growth. Makes decisions concerning land management, new equipment, and weed and frost control.	Works outdoors for long hours at certain times of the year. Needs at least a high school diploma, but a two-year technical program is desirable.
Park and Recreational Land Management Specialist Helps build, care for, and manage parks for hiking, camping, fishing, hunting, and gardening. Protects area's wildlife and natural resources.	Most work for the government, but some are managers of their own area. Often works outdoors. Needs a high school diploma, and often two years of college or technical school.

Career Description	Preparation and Qualifications
Pest Control Technician Destroys insects and animals that damage property and create health hazards.	Needs a high school diploma. During on-the-job training, learns to detect problems and handle poisons and equipment.
Pharmacologist Studies the useful and harmful effects of drugs on animals, including humans. Finds out if food preservatives and colorings are harmful. Compares findings with medical data.	May be employed in government laboratories or by drug manufacturers. Needs four years of college with a major in a natural science. An advanced degree is useful. Many drug companies have training programs.
Product Tester Analyzes samples of products to insure quality. May help develop new products. Sees that government regulations are being met.	Needs a high school diploma and some college-level chemistry.
Radiation Monitor Uses instruments to detect radioactive contamination in soil, water, or air. Checks exposure levels for workers in nuclear plants and calculates safe exposure periods. Instructs others in safety procedures.	Needs a high school diploma with courses in mathematics, physics, and chemistry to qualify for on-the-job training.
Range Manager Manages, develops, and protects rangelands and their resources. Establishes plans for grazing livestock, pest control, and restoring overgrazed land. Must balance the needs of livestock and wildlife.	Some jobs require stamina and willingness to work in remote areas. Most work for the federal government, but some are employed as consultants. Needs four years of college with a major in range management, agronomy, or forestry.
Sociologist Studies how groups of people interact in different societies. Collects and analyzes data on communities, ethnic and racial groups, and social change.	Most work for universities; some work for government agencies or private organizations. Needs an advanced degree in sociology.
Soil Conservationist Studies properties of different soils. Advises people on how to best use their soils, both for growing things and for building. Tests soils for nutrients and kinds and numbers of microorganisms.	Generally works outdoors. Most are employed by the federal government and need to pass a civil service examination. Needs four years of college with a major in a natural science or in an agricultural field. Summer work experience on a farm is desirable.
Soil Scientist Provides technical advice to farmers and ranchers. Plans and develops methods for soil erosion control, water conservation, and good use of land. Plans crop rotation, contour plowing, and re-vegetation of land.	Needed to complete the soil survey of all rural lands in the United States. May be employed by state and federal governments or by private businesses, research laboratories, or real estate companies. Works outdoors in all kinds of weather and in laboratories. Needs four years of college with a major in soil science, including courses in the biological, physical, and earth sciences.

Career Description	Preparation and Qualifications
Systems Analyst Analyzes scientific, technical, or environmental problems. Is a specialist in the field of electronic data-processing. Uses computers to solve problems. Identifies data needed and defines the way it is to be processed. Interprets results for management or customers. Prepares instructions for programmers.	Works mainly in large cities. Among the fastest-growing professional occupations. Needs four years of college, and experience in mathematics, science, engineering, accounting, or business. Learns to use electronic data-processing equipment in courses or on-the-job training.
Technical Writer Writes technical publications such as instruction manuals, articles for magazines and technical journals, and press releases. Puts complex information into clear, readable form.	Must pay attention to details, be able to work with others, have an inquisitive mind, and be able to work under the pressure of a deadline. Needs four years of college with a major in engineering or science and courses in writing, or a major in English or journalism and courses in science.
Urban Planner Develops plans to improve cities and solve urban problems such as traffic congestion, air pollution, and housing. Collects and analyzes data on factors affecting the use of land, such as trends in population and social and economic changes. Consults with local officials, scientists, and other specialists.	Is usually employed by local or regional governments. May have to pass a civil service examination. Needs at least four years of college with a major in city planning, architecture, landscape architecture, engineering, or social science. An advanced degree in planning is desirable. Must have knowledge of laws relating to the purchase of land.
Veterinarian Diagnoses, treats, and controls disease and injuries in animals. Advises on the care and breeding of animals. Prevents spread of animal disease to humans.	Works either with small pets or farm animals. May work irregular hours. Needs a Doctor of Veterinary Medicine degree (6-year program). Must have state license. May need period of practice under licensed veterinarian.
Wastewater-treatment Plant Operator Controls water pollution through treatment of home and industrial waste. Operates and maintains pumps, pipes, and valves. Reads meters and records data.	Should have mechanical aptitude and be able to perform simple calculations. May need to pass civil service examination or qualify for certification. Needs at least a high school diploma to start as a helper and learn skills on the job.
Wood Scientist and Technologist Studies biological and physical structure of wood. Develops new products and processes for wood and wood-based products. Tries to improve properties of wood such as drying speed, resistance to weather, and strength.	May be employed by wood-using industrial firms or government laboratories. This is a rapidly-growing field. Needs four years of college with a major in wood science from a forestry school.
Zookeeper Feeds animals, cleans cages, and watches for disease. Repairs cages and makes sure the environment is suitable for the animal.	Should be sensitive to the moods of animals. Needs a high school diploma with a course in biology.

Appendix F

Preface to the teacher of *Life Science Investigations: Man and the Environment*

Life Science Investigations began in 1965 as part of a general effort to improve K-12 science teaching. A group of science teachers and administrators from schools affiliated with the Educational Research Council of America met with a committee of consultants, and evolved a plan for a new middle school life science program. This plan called for the life science course to:

a. Emphasize an inquiry approach to human-oriented problems in biology,
b. Analyze similarities and differences between man and other organisms,
c. Investigate the interaction of man and his environment, and
d. Develop a perspective on some of the major biological problems facing man.

The First Experimental Edition was prepared and used in classrooms during the 1966–67 school year. Based on the recommendations of teachers, consultants, and the ERC science staff, plans were made for extensively reorganizing this edition. The Second Experimental Edition was subsequently written during the summer of 1967 and early months of 1968. Over 100 teachers and 16 000 students in schools affiliated with the Educational Research Council of America used and evaluated the Second Experimental Edition. Finally, when sufficient feedback had been gathered, plans were made to write a third, definitive edition.

So, in effect, *Life Science Investigations* represents almost five years of careful and continuous writing, field-testing, and revising. The end product is this new and exciting course in life science.

The Educational Research Council of America is a nonprofit corporation dedicated to developing exemplary curricular materials for grades K-12 in all subject areas for all students. The Council is composed of a central staff of about 200 and the 30 affiliated school systems. Taken together, they form a team for developing relevant, innovative, and effective instructional materials.

Life Science Investigations is only one of several courses that have been developed in this framework. Other courses for different grade levels are currently being devised, field-tested, and revised.

Frederick A. Rasmussen, *Coordinator*

Contributors to *Life Science Investigations: Man and the Environment* © 1974, 1971

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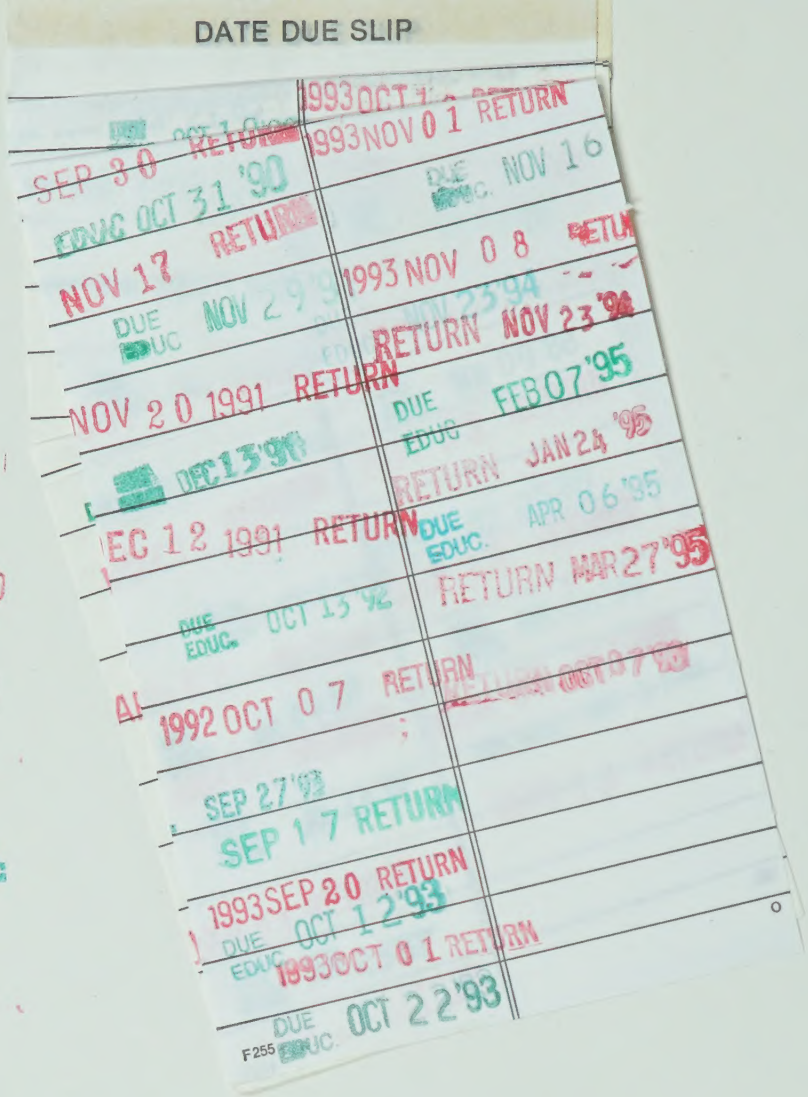
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